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Technical Resource Document for Obtaining Variances from the Secondary Containment Requirement of Hazardous Waste Tank Systems
Volume 2. Risk-Based Variance

ICF, Inc., Washington, DC

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Technical Resource Document for Obtaining Variances from the Secondary Containment Requirement of Hazardous Waste Tank Systems

Volume 2: Risk-Based Variance

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On July 14, 1986, EPA promulgated revised standards for hazardous waste storage and treatment tank system (51 FR 25422). These regulations require that all new and existing hazardous tank systems be provided secondary containment with release monitoring.

EPA recognizes that the goal of protecting human health and the environment might be achieved in ways other than secondary containment. Therefore, tank system owners or operators may apply for a variance from the secondary containment requirements of the hazardous waste tank standards. Both risk-based and technology-based variances can be obtained.

This document was developed to provide hazardous waste tank system owners and operators information for submitting a request for a variance. It was written in two volumes; Volume 1 covers technology-based variances, and Volume 2 covers risk-based variances.

A risk-based variance as discussed in Volume 2, may be granted if the tank system owner/operator can show that if a release occurs there will be no substantial hazard (present or future) to the environment and human health.

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EXECUTIVE SUMMARY

INTRODUCTION

On July 14, 1986, the U.S. EPA issued regulations for tank systems managing hazardous wastes (51 Federal Register 25422). The overall goal of the regulations is to ensure the protection of human health and the environment from the risks posed by releases from hazardous waste tank systems. The regulations address, among other issues, the design and installation of tanks, leak testing and detection, corrosion protection, structural integrity, responses to leaks, closure and post-closure, and secondary containment. The secondary containment requirement is a major feature of the July 14, 1986 regulation. The requirement applies immediately to all new tank systems (and systems to be reinstalled) and is to be phased in for existing systems. Variances from secondary containment are the subjects of this document (Volumes I and II).

The regulations provide two variances from the secondary containment requirement. The owner/operator of the tank system can petition the Regional Administrator (or, in some states, the appropriate State Official) for a variance from the secondary containment requirement in one of the following ways:

- Technology-Based Variance (Volume I). Alternative design or operating practices will detect leaks and prevent the migration of any hazardous waste beyond a zone of engineering control (i.e., an area under the control of the owner/operator that, upon detection of a release, can and will be readily cleaned up prior to the release of hazardous constituents to ground water or surface waters).

- Risk-Based Variance (Volume II). If a release does occur, there will be no substantial present or potential hazard to human health or the environment (not available for new underground tank systems or components due to Section 3004(o)(4) of RCRA).

The purpose of this volume (Volume II) of EPA's technical resource document for variances from secondary containment of hazardous waste tank systems is to provide guidance both to applicants seeking a risk-based variance and to permit writers reviewing risk-based variance demonstrations.

BACKGROUND

On June 26, 1985, the EPA announced it had determined that a substantial number of hazardous waste tank systems are likely to be leaking hazardous waste to the environment and that these releases could present significant risks to human health and the environment (50 Federal Register 26444). Three sources of information formed the basis for these determinations:

- Several EPA-sponsored studies;
- Information from the public, industry, and state and local governments, including survey results and studies; and
- Internal EPA information pertaining to damages, or threats of damage, caused by releases of hazardous wastes from tank systems.

This information also allowed the EPA to identify the major causes of tank system releases. These causes include external corrosion, tank structural failure, piping and ancillary equipment failures, improper tank system installation, and operator errors. Therefore, the EPA concluded that the best regulatory strategy for hazardous waste tank systems is one that focuses on sound primary containment and effective and rapid detection and response to leaks from the primary containment structure. The best means of ensuring these objectives for most tank systems is secondary containment with interstitial monitoring. Because technologies may exist which are as protective of human health and the environment as secondary containment, and because site-specific factors may exist which indicate that even a worst-case release of hazardous waste from a tank system would not pose a substantial present or potential hazard to human health or the environment, the two variances from secondary containment (i.e., the technology-based and the risk-based) were developed.

THE RISK-BASED VARIANCE

In order to receive a risk-based variance from the secondary containment requirements of hazardous waste tank systems, a tank system owner/operator must demonstrate to the EPA Regional Administrator (or State Official) that a release from the tank system will not pose substantial present or potential hazard to human health or the environment. A risk-based variance demonstration requires the permit applicant to determine the following (40 CFR 264.193(g)(2) (51 Federal Register 25475, July 14, 1986)):

(i) The potential adverse effects on ground water, surface water, and land quality taking into account:

  (A) The physical and chemical characteristics of the waste in the tank system, including its potential for migration;

  (B) The hydrogeological characteristics of the facility and surrounding land;

  (C) The potential for health risks caused by human exposure to waste constituents;

  (D) The potential for damage to wildlife, crops, vegetation, and physical structures caused by exposure to waste constituents; and

(E) The persistence and permanence of the potential adverse effects.

(ii) The potential adverse effects of a release on ground-water quality, taking into account:

(A) The quantity and quality of ground water and the direction of ground-water flow;

(B) The proximity and withdrawal rates of ground-water users;

(C) The current and future uses of ground water in the area; and

(D) The existing quality of ground water, including other sources of contamination and their cumulative impact on the ground-water quality.

(iii) The potential adverse effects of a release on surface water quality, taking into account:

(A) The quantity and quality of ground water and the direction of ground-water flow;

(B) The patterns of rainfall in the region;

(C) The proximity of the tank system to surface waters;

(D) The current and future uses of surface waters in the area and any water quality standards established for those surface waters; and

(E) The existing quality of surface water, including other sources of contamination and the cumulative impact on surface water quality.

(iv) The potential adverse effects of a release on the land surrounding the tank system, taking into account:

(A) The patterns of rainfall in the region; and

(B) The current and future uses of the surrounding land.

Because the appropriateness of a risk-based variance is determined by site-specific conditions, development of a risk-based variance demonstration requires extensive site-specific data. Therefore, this volume identifies the following: (1) the types of site-specific data that will generally be required for a risk-based variance demonstration; (2) potential sources of the required information; and (3) how the data are to be used in the demonstration.

A written notice of an owner/operator's intent to conduct and submit a demonstration for a risk-based variance from secondary containment of a hazardous waste tank system or component must be received by the U.S. EPA Regional Administrator (or State Official) within specific statutory deadlines

(40 CFR 264.193(h)(1) (51 Federal Register 25476)). Furthermore, the risk-based variance demonstration must be completed and received by the U.S. EPA Regional Administrator (or State Official) no more than 180 days after the written notice of intent to apply. Failure to meet these deadlines may result in the tank system or component becoming ineligible for the risk-based variance.

The risk-based variance application as described in Volume II is composed of essentially two parts:

- a health effects evaluation; and
- an environmental impact evaluation.

Both initially require similar information (e.g., physical, chemical, and toxicological characteristics of the waste, hydrogeological characteristics of the area, predicted exposure point concentrations). The health effects evaluation uses this information to estimate human health risk, while the environmental impact evaluation uses the information to describe the potential for damage to wildlife, crops, vegetation, and physical structures.

The steps described within this volume for completing the health effects evaluation are listed below.

1) Obtain information on the waste constituents, and select indicator chemicals (either all of or a subset of the chemicals handled within the tank system(s)). This step involves specifying the physical and chemical characteristics of the constituents, determining whether the use of indicator chemicals is appropriate and, if so, selecting indicator chemicals, and determining the potential worst-case release volumes.

2) Obtain information on the hydrogeology and surrounding environment. This step includes determining the proximity of the tank system to surface water and ground-water, the direction and velocity of ground-water flow, the depth and composition of the unsaturated zone, the patterns of regional rainfall, the current and future uses of ground water, surface waters, and the surrounding land, and the existing quality of ground water and surface water.

3) Identify current and future potential exposure pathways and estimate the exposure point concentrations of the indicator chemicals. If no current or future exposure pathways exist, then the demonstration of no substantial hazard is complete.

4) Compare the exposure point concentrations to established water and air quality standards. If acceptable established quality standards exist for all indicator chemicals, then the application is complete.

5) Estimate human intakes at the exposure points.

6) Assess the subchronic and chronic noncarcinogenic and potential carcinogenic toxicities of the chemicals.

7) Combine the intakes with the toxicities to provide an indication of the health risk.

The first three steps of the health effects evaluation (i.e., selecting indicator chemicals, obtaining site-specific information, and estimating exposure point concentrations), are identical to the first three steps of the environmental impact evaluation. The remaining step of the environmental impact evaluation involves a description of how the estimated exposure point concentrations will adversely affect the environment.

The level of detail required in the application is site-specific; it is affected by the particular waste streams handled, the tank system, the local hydrogeology, and the potential for human and environmental exposure. The applicant may decide to use a screening method for assisting in the decision of whether or not to proceed with the potentially expensive risk-based variance application. The other options are to seek a technology-based variance (Volume I) or comply with the secondary containment requirements.

The risk-based variance application is expected to parallel this volume of the technical resource document. That is, chapters or sections in the application should correspond to Chapters 2 through 8 of Volume II. Applicants will use their own discretion concerning which information is more appropriate as text and which is more appropriate as appendices to the application. Worksheets are also provided throughout the document. All are partially completed with illustrative examples, and blank worksheets are provided. These worksheets, or reasonable facsimiles, are to be filled out and submitted as part of the risk-based variance application.

An approach is recommended for summarizing the results, assumptions, and uncertainties of the risk-based variance analysis, for drawing a conclusion, and for preparing the supporting documentation. A variety of appendices are also provided. One appendix provides applicants with a procedure for helping decide whether to apply for a risk-based variance. This screening procedure consists of a series of questions to help the applicant identify tank systems that are exempt from the secondary containment requirement, tank systems that are not eligible for a risk-based variance, the basis for the risk-based variance, and potential future data gathering efforts. Another appendix provides a list of federal and state agencies, regional EPA offices and private organizations. These sources will be helpful in providing information for assessing surrounding land use, water use, and water quality characteristics. Still other appendices consist of data tables that contain key quantitative parameters for more than 260 chemicals, a description of the procedure used for determining toxicity constants for the selection of indicator chemicals, and blank copies of all worksheets presented in this volume of the technical resource document.

The EPA developed the risk-based variance for hazardous waste tanks in the context of other EPA rules, policies, and guidelines. These include the Ground-Water Protection Strategy (GWPS), the Location Standards (hydrogeologic vulnerability criteria), the Alternative Concentration Limit (ACL) Demonstration Guidance, the Superfund Exposure Assessment Manual, the Superfund Public Health Evaluation Manual, and the EPA Risk Assessment Guidelines, among others. Each document has a unique and specific purpose; however, the risk-based variance document incorporates the appropriate methodologies from the above documents that are relevant to developing a risk-based variance demonstration. As a result, the risk-based variance document provides consistent EPA policy and procedural recommendations for assessing risk associated with the release of contaminants from hazardous waste tanks.

CHAPTER 1

INTRODUCTION

The purpose of this volume (Volume II) of EPA's technical resource document for variances from secondary containment of hazardous waste tank systems is to provide guidance both to applicants seeking a risk-based variance and to permit writers reviewing risk-based variance demonstrations.[1] According to 40 CFR 264.183(g)(2) (51 Federal Register 25475, July 14, 1986),[2] in order to receive a risk-based variance from the secondary containment requirements of 40 CFR 264.193(a)-(f) (51 Federal Register 25474, July 14, 1986), a tank system owner or operator must demonstrate to the EPA Regional Administrator[3] that a release from the tank system will not pose substantial present or potential hazard to human health or the environment.[4] The risk-based variance only provides an exemption from the secondary containment requirements. The tank system is still subject to all other requirements, such as corrosion protection, integrity assessments, inspections, and corrective action. A risk-based variance demonstration requires the permit applicant to determine the following (40 CFR 264.193(g)(2) (51 Federal Register 25475, July 14, 1986)):

(i) The potential adverse effects on ground water, surface water, and land quality taking into account:

(A) The physical and chemical characteristics of the waste in the tank system, including its potential for migration (Chapter 2);[5]

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[1] Many states have developed non-degradation policies that prohibit or severely restrict the release of pollutants into the ground water. In such states, a risk-based variance from the secondary containment regulations may not be allowed unless the applicant can demonstrate that a release will not reach the ground water. Before attempting to obtain a risk-based variance, the prospective applicant should first check with the appropriate state government agency responsible for ground-water protection to determine whether a risk-based variance would be permissible under applicable state laws.

[2] All references to regulations for owners and operators of permitted hazardous waste facilities (40 CFR 264) also apply to interim status standards for owners and operators of hazardous waste facilities (40 CFR 265).

[3] In states that have received authorization from EPA to implement the RCRA program, demonstratons should be made to the cognizant State officials. Hereinafter, the term Regional Administrator refers to either the EPA or the State official as appropriate.

[4] The risk-based variance provision does not apply to new underground tank systems or components. Consequently, owners and operators must install secondary containment for new underground tank systems or components (51 Federal Register 25424, July 14, 1986).

[5] The chapters in parentheses refer to this volume of the technical resource document.

(B) The hydrogeological characteristics of the facility and surrounding land (Chapter 3);

(C) The potential for health risks caused by human exposure to waste constituents (Chapters 5 and 6);

(D) The potential for damage to wildlife, crops, vegetation, and physical structures caused by exposure to waste constituents (Chapter 7); and

(E) The persistence and permanence of the potential adverse effects (Chapter 2).

(ii) The potential adverse effects of a release on ground-water quality, taking into account:

(A) The quantity and quality of ground water and the direction of ground-water flow (Chapters 3 and 4);

(B) The proximity and withdrawal rates of ground-water users (Chapter 4);

(C) The current and future uses of ground water in the area, (Chapter 4); and

(D) The existing quality of ground water, including other sources of contamination and their cumulative impact on the ground-water quality (Chapter 4).

(iii) The potential adverse effects of a release on surface water quality, taking into account:

(A) The quantity and quality of ground water and the direction of ground-water flow (Chapters 3 and 4);

(B) The patterns of rainfall in the region (Chapter 3);

(C) The proximity of the tank system to surface waters (Chapter 3);

(D) The current and future uses of surface waters in the area and any water quality standards established for those surface waters (Chapter 4); and

(E) The existing quality of surface water, including other sources of contamination and the cumulative impact on surface water quality (Chapter 4).

(iv) The potential adverse effects of a release on the land surrounding the tank system, taking into account:

(A) The patterns of rainfall in the region (Chapter 3); and

(B) The current and future uses of the surrounding land (Chapter 4).

Because the appropriateness of a risk-based variance is determined by site-specific conditions, development of a risk-based variance demonstration requires extensive site-specific data. Therefore, this volume identifies the following: (1) the types of site-specific data that will generally be required for a risk-based variance demonstration; (2) potential sources of the required information; and (3) how the data are to be used in the demonstration.

In addition to requiring site-specific data, the risk assessment process requires the use of some site-specific procedures as well. For example, selection of appropriate soil and ground-water transport models depends on site-specific conditions. Thus, this volume does not specify how transport modeling is to be done, but instead provides general concepts, basic guidance, and sources of information on modeling. For other parts of the risk assessment process, such as determining chemical toxicity values, site-specific procedures are not required. In these instances, specific guidance is provided on how the risk assessment should be conducted. Where step-by-step procedures are not provided, extensive background discussion also is not provided. This is based on the assumption that an experienced professional would be needed to select the appropriate procedures. Suggestions of the type of professional needed for a particular situation are provided throughout this volume.

Before continuing, some terminology used in this volume in relation to hazardous waste tanks must be defined so that the reader has a clear understanding of what is being discussed. These terms and their definitions are listed below:

- tank - a stationary device designed to contain an accumulation of hazardous waste that is constructed primarily of non-earthen materials (e.g., wood, concrete, steel, plastic) that provide structural support (40 CFR 260.10 (51 Federal Register 25471, July 14, 1986)).

- tank system - a hazardous waste storage or treatment tank and its associated ancillary equipment (defined below) and containment system (if any) (40 CFR 260.10 (51 Federal Register 25471, July 14, 1986)), or a series of interconnected storage and/or treatment tanks that handle the same waste and their ancillary equipment and containment systems.

- ancillary equipment - any device that is used to distribute, meter, or control the flow of hazardous waste from its point of generation to a storage or treatment tank(s), between storage and/or treatment tanks, to a point of disposal on site, or to a point of shipment for disposal off site (40 CFR 260.10 (51 Federal Register 25471, July 14, 1986)). Ancillary equipment includes piping, fittings, flanges, valves, and pumps.

- tank system component - the individual tank(s) or ancillary equipment associated with a tank system (40 CFR 260.10 (51 Federal Register 25471, July 14, 1986)).

- tank system cluster - a group of tank systems that are in close enough proximity such that the transport of releases from the tank systems could be modeled realistically by aggregating the release volumes and chemical masses from the tank systems.

Exhibit 1-1 illustrates the use of these terms at a hypothetical facility. In addition to the above terms, the reader should be aware of the precise definitions of the four types of hazardous waste tanks referred to in this volume. These definitions are as follows (as defined in 40 CFR 260.10 (51 Federal Register 25471, July 14, 1986)):

- aboveground tank - a tank that is situated such that the entire surface area of the tank is completely above the adjacent surrounding surface and the entire surface of the tank (including the bottom) can be visually inspected.

- onground tank - a tank that is situated such that the bottom of the tank is on the same level as the adjacent surrounding surface so that the external tank bottom cannot be visually inspected.

- inground tank - a tank that has some portion of the tank wall situated within the ground, thereby preventing visual inspection of the external surface area of the tank that is in the ground.

- underground tank - a tank that is totally below the surface of and covered by the ground.

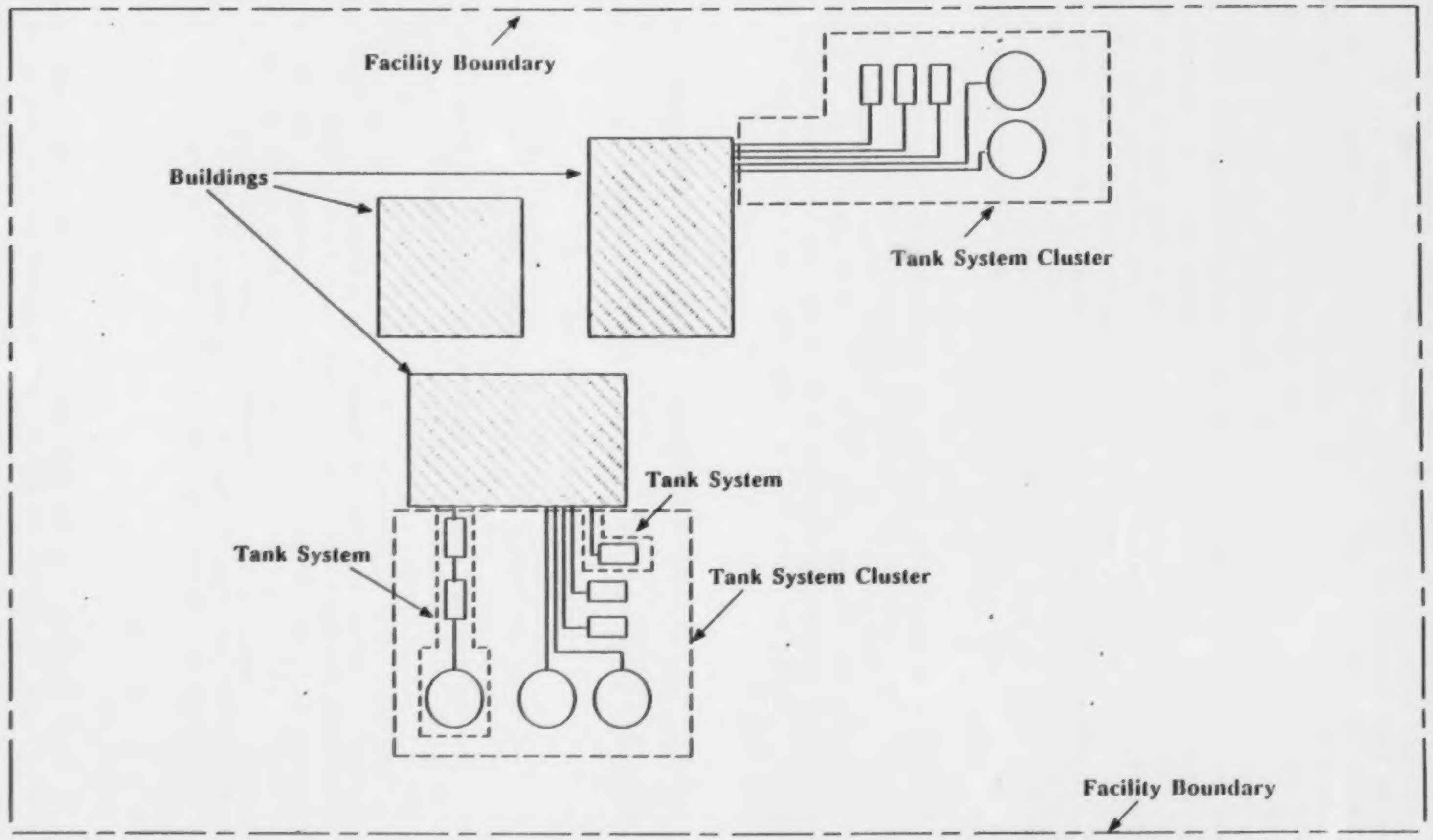
Some additional terms are identified as needed within the text.

Many facilities have more than one tank system or component that does not have secondary containment, yet the owner/operator may be applying for a risk-based variance for only some or one of them. These systems or components may not have secondary containment because of one of the following reasons: (1) the system or component is exempt from the secondary containment requirement (e.g., tank systems that are used to store waste absent of free liquids and are located within a building with an impermeable floor); (2) the system or component was previously granted a variance from the secondary containment requirement; or (3) the existing system or component has not yet reached 15 years of age.

In applying for a risk-based variance, the applicant must include in the demonstration of no substantial hazard the tank systems and components for which the variance is being sought as well as all tank systems or components previously granted a variance. This inclusion is required because the

Exhibit 1-1

PLAN VIEW OF HYPOTHETICAL FACILITY


Facility Boundary
Buildings
Tank System Cluster
Tank System
Tank System
Tank System Cluster
Facility Boundary

risk-based variance is based on no substantial hazard rather than no incremental substantial hazard. Consequently, for tank facilities that have several tank systems of different ages, the applicant may want to submit a variance application that includes all the tank systems for which a variance will eventually be sought. This procedure would avoid the necessity of future revisions to the risk-based variance application. In submitting revisions to an application, the additional tanks may result in substantial hazard. In this situation, the tank components which were previously granted a variance would be allowed to continue to operate without secondary containment and the additional tanks would not be granted a variance. For example, if tank A has previously been granted a risk-based variance and tank B is presently being evaluated for a risk-based variance, then the demonstration for tank B must include tank A in the evaluation. The reason for this inclusion is tank A may still release its hazardous waste even though it has been granted a risk-based variance. To assess the cumulative effect of this risk and the incremental risk from tank B, both must be considered together. If tanks A and B pose a substantial hazard, then tank B must be fitted with secondary containment. Tank A would still retain its variance.

The remainder of this chapter is organized as follows. Section 1.1 provides an overview of the variance demonstration process. Section 1.2 describes the relationship of this demonstration process to other environmental protection rules, policies, and guidelines. Section 1.3 discusses the procedures necessary to begin the variance application process.[6] Finally, Section 1.4 describes the organization of the remainder of this volume.

1.1 OVERVIEW OF THE RISK-BASED VARIANCE APPLICATION PROCESS

The risk-based variance application is composed of essentially two parts:

- a health effects evaluation; and
- an environmental impact evaluation.

Both initially require similar information (e.g., physical, chemical, and toxicological characteristics of the waste, hydrogeological characteristics of the area, predicted exposure point concentrations). The health effects evaluation uses this information to estimate human health risk, while the environmental impact evaluation uses this information to describe the potential for damage to wildlife, crops, vegetation, and physical structures. (It should be noted, however, that many environmental impacts also affect human health risk and should, therefore, be considered in the health effects evaluation as well as the environmental impact evaluation. For example, if crop contamination were to result in ingestion of contaminated food by humans, then this type of exposure should be considered in the health effects evaluation.)

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[6] Prior to applying for the variance, the applicant must provide written notice of intent to apply, accompanied by a schedule of the process, to the Regional Administrator (40 CFR 264.193(h) (51 Federal Register 25476)).

The steps described within this volume for completing the health effects evaluation are listed below.

1) Obtain information on the waste constituents, and select indicator chemicals (either all of or a subset of the chemicals handled within the tank system(s)) (Chapter 2).

2) Obtain information on the hydrogeology and surrounding environment (Chapters 3 and 4).

3) Identify current and future potential exposure pathways and estimate the exposure point concentrations of the indicator chemicals (Chapter 5). If no exposure pathways exist, then the demonstration of no substantial hazard is complete.

4) Compare the exposure point concentrations to established quality standards (Chapter 6, Section 1). If acceptable established standards exist for all indicator chemicals, then the health effects evaluation is complete.

5) Estimate human intakes at the exposure points (Chapter 6, Section 2).

6) Assess the subchronic and chronic noncarcinogenic and potential carcinogenic toxicities of the chemicals (Chapter 6, Section 3).

7) Combine the intakes with the toxicities to provide an indication of the health risk (Chapter 6, Section 4).

The first three steps of the health effects evaluation (i.e., selecting indicator chemicals, obtaining site-specific hydrogeologic information, and estimating exposure point concentrations (Chapters 2 through 5)), are identical to the first three steps of the environmental impact evaluation and, therefore, will already be completed. The remaining step of the environmental impact evaluation will involve a description of how these concentrations will adversely affect the environment (Chapter 7).

The level of detail required in the application is site-specific; it is affected by the particular waste streams handled, the tank system, the local hydrogeology, and the potential for human and environmental exposure. The applicant may decide to use a screening method (see Appendix A) for assisting in the decision of whether or not to proceed with the potentially expensive risk-based variance application. The other options are to seek a technology-based variance (Volume I) or comply with the secondary containment requirements.

The risk-based variance application should parallel this volume of the technical resource document. That is, chapters or sections in the application should correspond to Chapters 2 through 8. The applicant should use his or her own discretion concerning which information is more appropriate as text and wich is more appropriate as appendices to the application. Worksheets are provided throughout the document. All are partially completed with illustrative examples, and blank worksheets are provided in Appendix E. These worksheets, or reasonable facsimiles, are to be filled out and submitted as part of the risk-based variance application. All worksheets should contain the facility identifier, name of the analyst who completed the worksheet, and name of the quality control (QC) reviewer.

1.2 RELATIONSHIP TO OTHER RULES, POLICIES, AND GUIDELINES

The EPA developed the risk-based variance for hazardous waste tanks in the context of other EPA rules, policies, and guidelines. These include the Ground-Water Protection Strategy (GWPS), the Location Standards (hydrogeologic vulnerability criteria), the Alternative Concentration Limit (ACL) Demonstration Guidance, the Superfund Exposure Assessment Manual, the Superfund Public Health Evaluation Manual, and the EPA Risk Assessment Guidelines, among others. Each document has a unique and specific purpose; however, this technical resource document incorporates the appropriate methodologies from the above-mentioned documents that are relevant to developing a risk-based variance demonstration. As a result, this technical resource document provides consistent EPA policy and procedural recommendations for assessing risk associated with the release of contaminants from hazardous waste tanks. The following discussion describes the purpose and relationship of the aforementioned documents.

1.2.1 Ground-Water Protection Strategy (GWPS)

In August 1984, the Environmental Protection Agency (EPA) issued a Ground-Water Protection Strategy (GWPS) to encourage consistent protection of ground-water resources across EPA programs (e.g., Superfund cleanups, hazardous waste tank variances, and underground storage tank requirements). Through the process of classification, ground-water resources are separated into hierarchical categories on the basis of their value to society, use, and vulnerability to contamination. Each class is to be accorded a different level of protection. The core of the strategy is a differential protection policy that recognizes that different ground-water resources require different levels of protection. A three-tiered classification system was established as the vehicle for implementing this policy.

The Ground-Water Protection Strategy (GWPS) guidance[7] document for ground-water classification is a follow-up to the Ground-Water Protection Strategy that the Environmental Protection Agency (EPA) issued in August of 1984. EPA provided the GWPS Guidelines for public comment via a Federal Register notice December 3, 1986. The GWPS Guidelines are a major step in

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[7] EPA, Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy, Final Draft, Office of Ground-Water Protection, December 1986.

EPA's efforts to provide policy direction for EPA programs relating to ground water. The purpose of the GWPS document is two-fold: (1) to further define the classes, concepts, and key terms related to the classification system outlined in the Ground-Water Protection Strategy; and (2) to describe the procedures and information needs for classifying ground water.

The GWPS classification system consists of three general classes of ground water representing a hierarchy of ground-water resource values to society. These classes are:

- Class I - Special ground water;
- Class II - Ground water that is a current or potential source of drinking water; and
- Class III - Ground water that is not a current or potential source of drinking water.

The classification system is, in general, based on drinking water as the highest beneficial use of the resource. The system is designed to be used in conjunction with the site-by-site assessments typically conducted by the EPA program offices in issuing permits and variances, deciding on appropriate corrective action, etc.

A site-by-site approach to classifying ground water necessitates delineating a segment of ground water to which the classification criteria apply. The EPA has developed a Classification Review Area system that is based initially on a two-mile radius from the boundaries of the "facility" or the "activity." Within the Classification Review Area, a preliminary inventory of public supply wells, populated areas not served by public supply, wetlands and surface waters, is performed.

Class I ground waters are resources of unusually high value. They are highly vulnerable to contamination and are: (1) irreplaceable sources of drinking water; and/or (2) ecologically vital. Ground water that is highly vulnerable to contamination is characterized by a relatively high potential for contaminants to enter and/or to be transported within the ground-water flow system. Ground water may be considered "irreplaceable" if it serves a substantial population and if delivery of comparable quality and quantity of water from alternative sources in the area would be economically infeasible or precluded by institutional constraints. Ground water may be considered ecologically vital if it supplies a sensitive ecological system located in a ground-water discharge area that supports a unique habitat.

Class II ground waters are current and potential sources of drinking water and water having other beneficial uses. All non-Class I ground water currently used, or potentially available, for drinking water and other beneficial use is included in this category, whether or not it is particularly vulnerable to contamination. This class is divided into current sources of drinking water (Subclass IIA), and potential sources of drinking water (Subclass IIB).

Ground water is considered a current source of drinking water under two conditions. The first condition is the presence of one or more operating drinking-water wells (or springs) within the Classification Review Area. The second condition requires the presence within the Classification Review Area of a water-supply reservoir watershed (or portion of a water-supply reservoir watershed) designated for water-quality protection, by either state or local government. The concept of a current source of drinking water is rather broad by intent.

A potential source of drinking water is one which is capable of yielding a quantity of water to a well or spring sufficient for the needs of an average family. Drinking water is taken specifically as water with a total dissolved solids (TDS) concentration of less than 10,000 mg/l, which can be used without treatment, or which can be treated using methods reasonably employed in a public water-supply system. The sufficient yield criterion has been established at 150 gallons/day.

Class III ground waters are resources that are not potential sources of drinking water. These ground waters are of limited beneficial use because they are either saline or otherwise contaminated beyond levels which would allow use for drinking or other beneficial purposes. This class includes ground waters that: (1) have a total dissolved solids (TDS) concentration over 10,000 mg/l; or (2) are so contaminated by naturally occuring conditions, or by the effects of broad-scale human activity (i.e., unrelated to a specific activity), that they cannot be cleaned up using treatment methods reasonably employed in public water-supply systems.

Class III is subdivided primarily on the basis of the degree of interconnection with surface waters or adjacent ground waters of a higher class. In addition, Class III encompasses those very rare settings where there is insufficient ground water within the Classification Review Area at any depth to meet the needs of an average size family. Such ground waters, therefore, are not potential sources of drinking water.

The risk-based variance assessment process described in this volume is conducted on a site-by-site basis and includes a hydrogeologic characterization consistent with GWPS Guidelines. While the purpose of the risk-based variance hydrogeologic characterization is not to classify the site's ground water into Class I, Class II, etc., the risk-based variance assessment does evaluate all of the same site-specific characteristics used by the GWPS Guidelines. In general, a risk-based variance is more likely to be appropriate for tank systems located in areas with Class III ground water. Tank systems located in areas with Class I ground water are unlikely to be eligible for a risk-based variance.

1.2.2 Location Standards (Hydrogeologic Vulnerability Criteria)

EPA's Location Standards manual[13] was prepared in response to the Hazardous and Solid Waste Amendments of 1984 requirement that EPA publish guidance criteria identifying areas of vulnerable hydrogeology. The purpose of such location standards is to provide RCRA permit writers with a standardized technical method for evaluating hydrogeologic data submitted in hazardous waste land treatment, storage, and disposal facility permit applications to determine if the facilities are located in "areas of vulnerable hydrogeology."

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[13] EPA, Criteria for Identifying Areas of Vulnerable Hydrogeology Under RCRA: Statutory Interpretative Guidance Manual for Hazardous Waste Land Treatment, Storage, and Disposal Facilities, Interim final report submitted to Office of Solid Waste, July 1986.

EPA considers "areas of vulnerable hydrogeology" to be areas in which the predominant natural hydrogeological conditions are conducive to the subsurface migration of contaminants in a manner that may adversely affect drinking water sources, sensitive ecological systems, or nearby residents. EPA intends to incorporate consideration of the hydrogeologic vulnerability of a facility's location into RCRA permitting decisions. Currently, EPA will only be able to do so to a limited extent due to the constraints of existing regulations. However, once regulations specifying criteria for acceptable locations required under HSWA Section 3004(O)(7) have been promulgated, EPA will have much greater flexibility in considering the hydrogeologic vulnerability of a facility's location in permitting decisions.

OSW is developing an integrated ground-water strategy that will consider how such hydrogeologic vulnerability criteria may be applied to facility permitting decisions (e.g., risk-based variances). In addition, it will evaluate the relationship of each of the major components of the RCRA program mandated by HSWA. The integrated OSW ground-water strategy is a response to the previously discussed 1984 Ground-Water Protection Strategy (GWPS), which called for program offices to develop policies for ground-water protection against a broad framework of ground-water classification and protection. The OSW strategy not only characterizes the quality and use of ground water, but also characterizes how vulnerable that ground water is to contamination as a result of the site's geology.

A risk-based variance demonstration includes a site hydrogeologic characterization that identifies how vulnerable the potentially affected ground water is to contamination from a tank site release. Such a site characterization must consider all the same factors that would be considered according to the location standards guidance. Thus, as the location standards become incorporated into the RCRA permitting process, they can also be used for evaluating risk-based variances.

1.2.3 Alternate Concentration Limit (ACL) Guidance

The Alternate Concentration Limit (ACL) Guidance[9] provides guidance for hazardous waste facilities seeking variances from ground-water background contaminant concentration levels or RCRA adopted maximum ground-water contaminant concentration limits (MCLs). The principal elements of the ground-water protection standard are discussed in 40 CFR 264.90. All land treatment, storage, and disposal (TSD) units must install a ground-water monitoring program to ensure that ground-water standards are met. For each hazardous constituent entering the ground water from a regulated unit, background concentrations or MCLs establish the limit beyond which degradation of ground-water quality will not be allowed.

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[9] EPA, Alternate Concentration Limit Guidance Based on Section 264.94(b) Criteria, Part I: ACL Policy and Information Requirements, Draft report submitted to the Office of Solid Waste, December 1986 (currently unavailable).

Variances from these standards, in the form of an ACL, are available if the applicant can demonstrate that alternative constituent concentration levels will not pose a substantial present or potential hazard to human health or the environment. An ACL demonstration requires not only characterizing the site hydrogeology, similar to that done for the Location Standards, but also characterizing the hazardous waste constituents from the point of release to the point of exposure. 40 CFR 264.94 discusses the "Alternate Concentration Limit" and lists 10 criteria to be applied in ACL demonstrations.

An ACL demonstration is essentially a risk assessment and risk management process in which a determination of acceptable ground-water contamination is made. Site-specific information, such as local hydrogeologic characteristics, the facility's waste constituents, and local environmental factors, is needed to assess the potential impact on human health and the environment of each hazardous constituent present in the ground water.

To establish ACLs, two points must be defined on a RCRA facility's property: (1) the point of compliance (POC); and (2) the point of exposure (POE). The POC is the point in the uppermost aquifer, on the immediate downgradient side of the RCRA regulated unit, where ground-water monitoring takes place and the ground-water protection standard is set. The ACL, if it is established, would be set at this point. The POE, on the other hand, is the point at which it is assumed a potential receptor can come in contact with the ground water. Therefore, the ground-water quality at the POE must be protective of that receptor.

While both the ACL demonstration and risk-based variance process for hazardous waste tanks require site-specific risk assessments, the ACL process depends on ground-water monitoring to ensure that the ACL will not be exceeded. Such ground-water monitoring is already required at all land TSD units according to 40 CFR 264.97. The risk-based variance demonstration for tanks, however, does not rely on ground-water monitoring to establish and monitor an acceptable level of contamination. Instead, the risk-based variance demonstration for tanks depends on an analysis of a potential worst-case release and the demonstration that, because of the tank system's combination of waste composition and the hydrogeology of the site, even a worst-case release will not pose a substantial present or potential risk to human health and the environment.

1.2.4 Superfund Exposure Assessment and Public Health Evaluation Manuals

The Superfund Exposure Assessment[10] and the Superfund Public Health Evaluation[11] manuals provide guidance for conducting portions of the remedial investigations (RI) and feasibility studies (FS) for Superfund sites. The purpose of the remedial investigation is to acquire the field data needed to determine the extent of existing contamination at the site (in the absence of any control measures). In the feasibility study, these data are used to evaluate site-related exposure and present or potential risk to human health and the environment. The remedial investigation and the feasibility study are major components in the remedial response process for Superfund sites.

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[10] EPA, Superfund Exposure Assessment Manual, Draft, Office of Emergency and Remedial Response, January 1986.

[11] EPA, Superfund Public Health Evaluation Manual, Office of Emergency and Remedial Response, October 1986.

The risk-based variance demonstration for hazardous waste tanks, as described in this volume, is based to a large extent on the risk assessment methodologies recommended in the Superfund Public Health Evaluation Manual. Much of the guidance on exposure assessment is based on the Superfund Exposure Assessment Manual. The methods recommended in these manuals are particularly appropriate because the hazardous waste tank risk-based variance requires the evaluation of risk posed by a presumed worst-case uncontrolled release. In addition, these manuals have already been successfully used for Superfund sites.

Superfund Exposure Assessment Manual

The Superfund Exposure Assessment Manual presents an integrated methodology for the analyses conducted during the RI/FS. This methodology includes the following three major components required to assess human population exposure to contaminants released from uncontrolled hazardous waste sites: (1) analysis of toxic contaminants released from a subject site; (2) determination of the environmental fate of such contaminants; and (3) evaluation of the nature and magnitude of human population exposure to toxic contaminants. These major analytical components are conducted in sequence to qualitatively and quantitatively track the migration of contaminants through environmental media to points of contact with human populations.

The general framework for conducting an integrated exposure analysis involves identifying each on-site source of each target chemical release to specific environmental media. Emissions are characterized by types and amount of chemicals involved, and a determination is made of the level of release (mass loading) of each chemical to each affected medium. The results of the release analysis step provide the basis for evaluating the potential for contaminant transport or transformation and environmental fate. This analysis is also chemical- and medium-specific.

Environmental fate analysis produces results that describe the extent and magnitude of environmental contamination (i.e., contaminant concentrations in specific environmental media). These results are used to predict human population contact with chemicals emanating from the site. Exposed population analysis results in the identification, enumeration, and characterization of those population segments likely to be exposed. The assessment concludes with an integrated exposure analysis. In this step, individual chemical-specific exposure estimates for each exposure route (i.e., inhalation, ingestion of drinking water and/or food, dermal contact) are developed. In cases where a population group experiences more than one exposure by a given route, exposures are summed to develop a cumulative exposure value for the route involved.

The Superfund Exposure Assessment manual is designed for three specific purposes. First, the overall analytical process outlined provides a framework for the comprehensive assessment of human exposure associated with uncontrolled hazardous waste sites. It ensures that all pertinent contaminant releases and exposure routes are considered, and that an appropriate level of analytical detail is applied to each component of the evaluation to support the public health evaluation process. Second, application of this framework supports the development of exposure assessments that are consistent from site to site. That is, application of the same analytical philosophy and overall procedure to each site will ensure that results obtained are comparable among sites, and will provide a means of documenting that each site receives adequate evaluation. Third, the procedures presented in this manual reflect state-of-the-art methods for conducting the various component analyses that make up an exposure assessment.

Superfund Public Health Evaluation Manual

The Superfund Public Health Evaluation Manual details the information requirements and analytical procedures necessary to conduct a public health evaluation during a feasibility study. The public health evaluation component of the feasibility study defines the type and extent of hazards to public health presented by a Superfund site in the absence of remedial action. It is based in large part on the previously discussed exposure assessment that evaluates: (1) the type and extent of contamination released from a site to the environmental media; (2) the environmental transport and transformation of contaminants following releases; and (3) the magnitude of contact with human populations.

The results of the exposure assessment may aid the public health evaluation in one of two ways. Measured or estimated environmental contaminant concentrations can be compared with public health standards or criteria that identify acceptable concentrations of contaminants in specific environmental media. This comparison is used to directly assess the potential public health impact. Alternatively, in the absence of such standards/criteria, the public health evaluation process evaluates exposure estimates using relevant toxicological data to determine the magnitude of the health hazard posed by the uncontrolled site.

The Superfund Public Health Evaluation Manual covers the two key elements of a public health evaluation that should be addressed in any feasibility study: (1) the baseline public health evaluation; and (2) the public health analysis of remedial alternatives. A baseline public health evaluation is an analysis of site conditions in the absence of remedial action. It provides the remedial project manager with an understanding of the nature of chemical releases from the site, the pathways of human exposure, and a measure of the threat to public health as a result of releases. The information developed in the baseline analysis provides input for developing and evaluating remedial alternatives. In addition, the baseline evaluation satisfies the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) requirement to complete a detailed analysis of the no-action alternative, including an evaluation of public health impacts.

Development of design goals for remedial alternatives is the second key phase of the public health evaluation. The manual describes specific procedures for comparing health risks and developing design goals for remedial measures. The process builds on information collected and evaluated in the baseline evaluation and closely follows the guidelines in the NCP and EPA's policy on CERCLA compliance with the requirements of other environmental statutes.

The public health evaluation guidance provides a framework that must be adapted to individual site characteristics. These site characteristics include the following:

- number and identity of chemicals present;
- availability of appropriate standards and/or toxicity data;
- number and complexity of exposure pathways (including complexity of release sources and transport media);
- necessity for precision of the results, which in turn depends on site conditions such as the extent of contaminant migration, proximity, characteristics and size of potentially exposed populations, and enforcement considerations (additional quantification may be warranted for some enforcement sites); and
- quality and quantity of available monitoring data.

The Superfund Public Health Evaluation Manual provides the recommended procedures for comparing the different risk estimates obtained from the exposure assessments for alternative clean-up strategies. The results of both the exposure and the public health assessments provide critical information for those responsible for the selection and implementation of remedial options at Superfund sites.

1.2.5 EPA Guidelines for Health Risk Assessments[12]

In September 1986 (51 Federal Register 33992, September 24, 1986) EPA issued five guidelines for assessing the health risks of environmental pollutants. These guidelines are as follows:

- Guidelines for Carcinogen Risk Assessment;
- Guidelines for Estimating Exposures;
- Guidelines for Mutagenicity Risk Assessment;

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[12] Other useful risk assessment information can be found in the following document: EPA, Superfund Risk Assessment Information Directory, Office of Information Resources Management and Office of Toxic Substances, November 1986.

- Guidelines for the Health Risk Assessment of Suspected Developmental Toxicants; and

- Guidelines for the Health Risk Assessment of Chemical Mixtures.

The risk-based variance for hazardous waste tanks is consistent with the guidelines mentioned above, and, in particular, uses the Guidelines for Estimating Exposures and the Guidelines for the Health Risk Assessment of Chemical Mixtures as a basis for some of the procedures documented in this manual.

The Guidelines for Estimating Exposures (51 Federal Register 34042, September 24, 1986) emphasize that risk assessments will be performed on a case-by-case basis, and provide a general framework for carrying out human or non-human exposure assessments. The document lays out a set of questions to be considered in carrying out an exposure assessment, and these questions have been incorporated into the risk-based variance manual. The Guidelines emphasize that reliable measurements should be used wherever possible to complement modeling, and that the exposure assessment process should be coordinated with the toxicity effects assessment. The exposure assessment is divided into a preliminary phase in which data are compiled and the most likely areas of exposure are identified. Results from the preliminary phase are then compiled with toxicity information to perform a preliminary risk analysis and to decide whether an in-depth exposure assessment is necessary or there is no need for further exposure information. Because the assessment of a risk-based variance is based on potential exposure to chemicals, it is always necessary to perform the in-depth analysis based on modeling of a leak from the tank.

The Guidelines for the Health Risk Assessment of Chemical Mixtures (51 Federal Register 34014, September 24 1986) are designed to promote a consistent Agency approach for evaluating data on chronic and subchronic effects of chemical mixtures. The document emphasizes the principles of various sciences that are necessary to assess health risk from exposure to chemical mixtures, and discusses procedures for the analysis and evaluation of the available data. Because of uncertainties inherent in predicting the magnitude and nature of toxicant interactions, the assessment of health risk from chemical mixtures must include a thorough discussion of all assumptions; the guidelines recommend different approaches to risk assessment depending on the nature and quality of the data. The complexity of the issue, and the relative paucity of empirical data upon which to base generalizations, led the Agency to emphasize flexibility, judgment, and a clear articulation of the assumptions and limitations in risk assessments of chemical mixtures.

For each risk assessment, the uncertainties should be discussed and the overall quality of the risk assessment should be documented. The guidelines discuss the uncertainties and limitations in some detail, and document mathematical models for the measurement of joint action of chemicals. The evaluation of risk for the risk-based variance demonstration uses the same mathematical models to calculate hazard indices and carcinogenic incremental risk as presented in EPA's Guidelines for Health Risk Assessment of Chemical Mixtures.

1.3 INITIATING THE VARIANCE APPLICATION

Before beginning the risk-based variance demonstration, some initial steps must be completed. The first is that a written notice of an owner's or operator's intent to conduct and submit a demonstration for a risk-based variance from secondary containment of a hazardous waste tank system or component must be received by the U.S. EPA Regional Administrator within specific statutory deadlines (40 CFR 264.193(h)(1) (51 Federal Register 25476)) (see Appendix A, Section A.2.1.4). Furthermore, the risk-based variance demonstration must be completed and received by the U.S. EPA Regional Administrator no more than 180 days after the written notice of intent to apply. Failure to meet these deadlines may result in the tank system or component becoming ineligible for the risk-based variance.

The written notice of intent to apply must include the following:

(1) a map, with accompanying text, indicating facility location;

(2) a map, with accompanying text, indicating the location and other identifying characteristics of each tank system or component that will be included in the variance demonstration;

(3) the age of each tank system or component (if unknown, then facility age);

(4) a description of the steps being followed to demonstrate no substantial hazard;

(5) a timetable for completing each of the steps; and

(6) a quality assurance plan.

Worksheet 1-1 is provided for addressing items 4 and 5. When completed, it can be submitted as part of the notice of intent to apply. The sheet contains a "milestone" chart for indicating the anticipated completion date of each step. Place a check mark under the appropriate week and include the actual date.

Another step that is part of the written notice of intent to apply is the development of a quality assurance (QA) plan. It is the Office of Solid Waste's policy[13] that all data will be scientifically valid, defensible, and of known and acceptable precision and accuracy. The data will be of sufficient known quality so as to withstand scientific and legal challenge relative to the use for which the data are obtained. To ensure that the data are of known and acceptable quality, adequate QA must be applied throughout the data-generating process. To achieve this goal, data quality objectives must be specified prior to data collection activities. This aspect of the

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[13] EPA, Quality Assurance Program Plan for the Office of Solid Waste, Office of Solid Waste, September 1986.

WORKSHEET 1-1

TIMETABLE FOR DEMONSTRATION OF RISK-BASED VARIANCE FROM SECONDARY CONTAINMENT

INSTRUCTIONS:

1. Fill in Starting Date and Finishing Date.
2. Place a ✓ at expected time of completion for each activity.
3. Next to ✓, place expected date in parenthesis (e.g., (10/25/88))

Facility ID: ____________________
Date: ____________________
Analyst: ____________________
Quality Control: ____________________

Starting Date ☐

Finishing Date ☐

ACTIVITY	WEEK 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
I. Source Characterization																										
a. Identify Physical and Chemical Characteristics of Constituents																										
b. Select Indicator Chemicals																										
c. Determine Worst Case Release Volumes																										
II. Hydrogeological Characteristics																										
a. Characterize Climate																										
b. Characterize Regional and Site Geology																										
c. Characterize Unsaturated and Saturated Zones																										
d. Characterize Surface Water																										
III. Surrounding Land Use, Water Use, and Water Quality Characteristics																										
a. Characterize Ground-Water Use and Quality																										
b. Characterize Surface Water Use and Quality																										
c. Characterize Surrounding Land Use and Quality																										

WORKSHEET 1-1
TIMETABLE FOR DEMONSTRATION OF RISK-BASED VARIANCE FROM SECONDARY CONTAINMENT
(Continued)

Starting Date ☐

Finishing Date ☐

WEEK

ACTIVITY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
IV. Exposure Point Concentration																										
a. Identify Exposure Pathways																										
b. Estimate Exposure Point Concentrations																										
V. Health Effects Evaluation																										
a. Compare Exposure Point Concentrations to Established Health Standards																										
b. Estimate Chemical Intakes																										
c. Determine Chemical Toxicities																										
d. Characterize Risk																										
VI. Environmental Impact Evaluation																										
a. Compare Exposure Point Concentrations to Quality Standards																										
b. Derive Site Specific Criteria																										
c. Evaluate Site Specific Exposure Points																										
VII. Preparation of the "No-Substantial Hazard" Demonstration																										
a. Summarize Results of the Risk-Based Assessment																										
b. Prepare Supporting Documentation																										
c. Submit to Regional Administrator																										

initial phase of planning is the basis for the QA plan that is developed. The QA plan becomes the basis for monitoring and evaluating data collection activities to ensure that the data quality objectives are met. Part of this plan has already been incorporated into the worksheets by a requirement that the quality control (QC) reviewer initial the worksheet.

Again, submission of the demonstration for a risk-based variance (see Chapter 8) must be no more than 180 days after providing written notice of intent to apply. Therefore, the timetable in Worksheet 1-1 extends across 180 days, beginning with the submission of written notice of intent to apply and ending with the submission of the variance application.

1.4 ORGANIZATION OF TECHNICAL RESOURCE DOCUMENT: VOLUME II

The remainder of this volume of EPA's technical resource document for variances from secondary containment of hazardous waste tank systems is organized as follows:

- **Chapter 2 -- Source Characterization**

  This chapter describes methods for characterizing the potential source of contamination. The source characterization includes: (1) specifying the physical and chemical characteristics of the constituents; (2) determining whether the use of indicator chemicals is appropriate and, if so, selecting indicator chemicals; and (3) determining the potential worst-case release volumes.

- **Chapter 3 -- Hydrogeologic Characterization**

  This chapter discusses the recommended approach for characterizing the hydrogeology surrounding the tank system and facility. Such characterizations include: (1) determining the proximity of the tank system to surface water and ground-water; (2) direction and velocity of ground-water flow; (3) depth and composition of the unsaturated zone; and (4) patterns of regional rainfall.

- **Chapter 4 -- Surrounding Land Use, Water Use, and Water Quality Characteristics**

  The methodologies for determining surrounding water use and water quality characteristics are described in this chapter. In this chapter the applicant examines: (1) the proximity and withdrawal rates of ground-water uses; (2) the current and future uses of ground water, surface waters, and the surrounding land; and (3) the existing quality of ground water and surface water.

- **Chapter 5 -- Identifying Exposure Pathways and Estimating Exposure Point Concentrations**

  This chapter discusses the estimation of potential exposure point concentrations. Methodologies for identifying exposure pathways and estimating exposure point concentrations are provided. The estimated exposure point concentrations are then used in the health and environmental effects evaluations described in Chapters 6 and 7.

- Chapter 6 -- Health Effects Evaluation

  This chapter explains the evaluation of potential health effects by: (1) comparing exposure point concentrations to established acceptable concentration levels; (2) estimating potential human intake of waste constituents; (3) determining the chemical toxicity values; and (4) estimating the potential carcinogenic and non-carcinogenic risks based on the chemical toxicity values and intake rates.

- Chapter 7 -- Environmental Impact Evaluation

  This chapter describes the evaluation of potential environmental impacts. Such an evaluation includes: (1) comparing exposure point concentrations to established quality standards for ground water, surface water, and land; and (2) estimating the potential for damage to wildlife, crops, vegetation, and physical structures.

- Chapter 8 -- Summarizing the Risk-Based Variance Application

  This chapter describes the recommended approach for summarizing the results of the risk-based variance analysis and preparing the supporting documentation.

- References

  The list of references includes all journal articles, books, and documents that are cited in the text or footnotes of this volume. Other useful references are also listed.

- Appendix A -- Preliminary Screening for Risk-Based Variance

  This appendix provides applicants with a procedure for helping them decide whether to apply for a risk-based variance. The screening procedure consists of a series of questions to help the applicant identify tank systems that are exempt from the secondary containment requirement, tank systems that are not eligible for a risk-based variance, the basis for the risk-based variance and potential future data gathering efforts.

- Appendix B -- Information Sources for Environmental and Hydrogeologic Information

  This appendix provides a list of federal and state agencies, regional EPA offices and private organizations. These sources will be helpful in providing information for assessing surrounding land use, water use and water quality characteristics.

- Appendix C -- Summary Tables for Chemical-Specific Data

  This appendix consists of data tables that contain key quantitative parameters for more than 260 chemicals. Parameters relate to physical, chemical, fate and toxicological properties of the chemicals. These specific chemicals are included because of the amounts of readily available toxicity information rather than because of their likely presence within hazardous waste tank systems.

- **Appendix D -- Detailed Procedures for Determining Toxicity Constants for Indicator Chemical Selection**

  This appendix describes the procedure used for determining toxicity constants that are used for the selection of indicator chemicals. The procedure can be used for specific chemicals not listed in Appendix C.

- **Appendix E -- Blank Worksheets**

  This appendix includes blank copies of all worksheets presented in this volume. These worksheets will be completed by the applicant and submitted as part of the risk-based variance application.

CHAPTER 2

SOURCE CHARACTERIZATION

This chapter describes the information that is required to characterize tank systems and components for a risk-based variance application. This characterization focuses on elements of tank systems that may adversely affect human health and the environment in the absence of secondary containment. Section 2.1 presents a methodology for characterizing the physical and chemical properties of the constituents handled within tank systems. Section 2.2 describes a procedure for applicants with tank systems that contain many hazardous waste constituents to rank and select the waste constituents that are highly toxic, present in high concentrations, and/or are persistent (indicator chemicals). The final section, Section 2.3, presents a methodology for estimating potential worst-case release volumes and release masses of contaminants associated with tank systems. These release volumes and masses are necessary to estimate exposure point concentrations (see Chapter 5). Following completion of the procedures discussed in this chapter, the applicant should have identified information relevant to the particular tank systems or components for which a variance is sought. Exhibit 2-1 provides an overview of the source characterization process.

2.1 PHYSICAL, CHEMICAL, AND TOXICOLOGICAL CHARACTERISTICS OF CONSTITUENTS

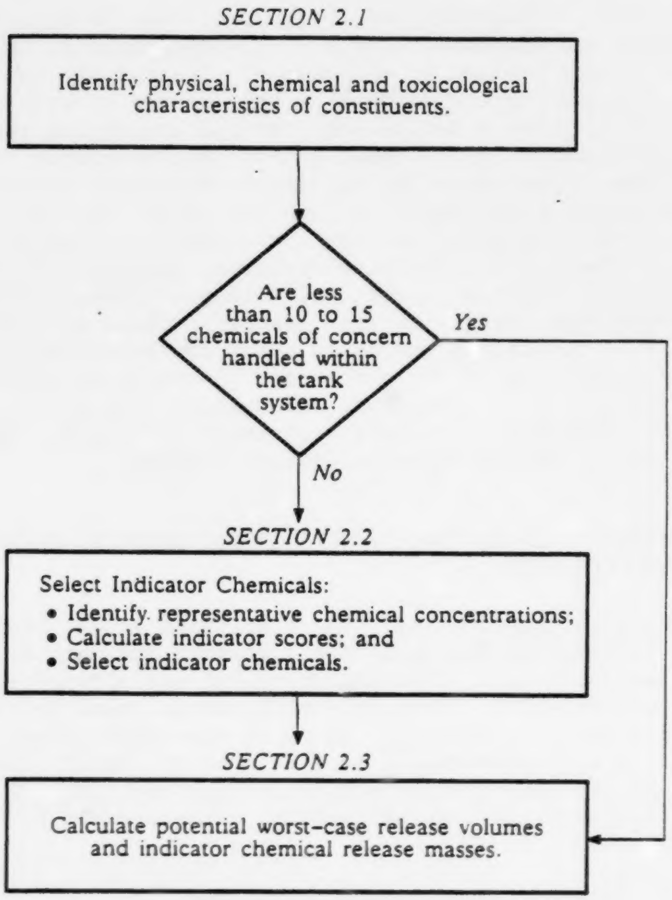
The physical and chemical characteristics of the constituents handled within a tank system determine the transport and fate of the constituents within the environment. The toxicological characteristics of the constituents indicate the potential hazard to human health posed by the constituents. This section presents the characteristics of the constituents that the applicant (or a qualified professional, such as a toxicologist) should identify and use in the indicator chemical selection process (Section 2.2). In addition, many of the characteristics may be used for transport and fate modeling (see Chapter 5).

2.1.1 Physical and Chemical Properties

Physical and chemical properties that affect transport and fate of constituents include:

- water solubility;
- vapor pressure;
- Henry's law constant;
- organic carbon partition coefficient;
- octanol-water partition coefficient;
- persistence (i.e., half-life);
- specific gravity;
- viscosity; and
- oxidation state.

Exhibit 2-1
OVERVIEW OF SOURCE CHARACTERIZATION



SECTION 2.1

Identify physical, chemical and toxicological characteristics of constituents.

Are less than 10 to 15 chemicals of concern handled within the tank system?

SECTION 2.2

Select Indicator Chemicals:

- Identify representative chemical concentrations;
- Calculate indicator scores; and
- Select indicator chemicals.

SECTION 2.3

Calculate potential worst-case release volumes and indicator chemical release masses.

The applicant should first list all chemicals of concern on Worksheet 2-1. Chemicals (i.e., constituents) of concern include all RCRA-listed Appendix VIII hazardous constituents[1] currently or likely to be handled within the tank systems for which the applicant is seeking a risk-based variance or for which a risk-based variance has previously been approved. A risk-based variance will apply only to the tank systems and chemicals evaluated in the demonstration of no substantial hazard. Consequently, before additional chemicals are handled at a future date, the applicant must either revise and resubmit the risk-based variance application, apply for a technology-based variance for the tank system(s) handling the new chemicals, or provide secondary containment for the tank system(s) handling the new chemicals.

Next, the applicant should record on Worksheet 2-1 the physical and chemical properties for each chemical of concern. The Chemical Abstract Service (CAS) number, water solubility, organic carbon partition coefficient, vapor pressure and Henry's law constant can be found for many chemicals in Exhibit C-1. Half-lives of specific chemicals can be found in Exhibit C-2. Densities, viscosities, and oxidation states can be obtained from chemical handbooks.[2][3] These physical and chemical properties may be used in the selection of indicator chemicals. They are also usually necessary parameters for transport models.

For chemicals not listed in Appendix C, the applicant should determine values using sources listed in Appendix C or other standard references. Also, estimation techniques are available for many physical/chemical parameters.[4][5] The applicant is encouraged to use estimation techniques in the absence of experimental data, as long as the procedures are documented.

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[1] 40 CFR Part 261, Appendix VIII.

[2] Robert C. Weast, Ph.D., ed., CRC Handbook of Chemistry and Physics, 64th ed. (Boca Raton: CRC Press, Inc., 1983).

[3] Robert C. Reid, John M. Prausnitz, and Thomas K. Sherwood, The Properties of Gases and Liquids, 3rd ed. (New York: McGraw-Hill, 1977).

[4] W.J. Lyman, W.F. Reehl, and D.H. Rosenblatt, Handbook of Chemical Property Estimation Methods (New York: McGraw-Hill, 1982).

[5] W.R. Mabey, J.H. Smith, R.T. Podoll, H.L. Johnson, T. Mill, T.W. Chou, J. Gates, I.W. Patridge, H. Jaber, and D. Vandenberg, Aquatic Fate Process Data for Organic Priority Pollutants (Washington, D.C.: Monitoring and Data Support Division, Office of Water Regulations and Standards, 1982).

WORKSHEET 2-1

PHYSICAL AND CHEMICAL CHARACTERISTICS OF CONSTITUENTS

INSTRUCTIONS:

1. List all chemicals and their Chemical Abstract Service (CAS) number.

2. Refer to Exhibit C-1 and C-2 and record each chemical's solubility, vapor pressure, Henry's law constant, Koc, log Kow, and half-lives in water, soil, and air. Refer to chemical handbooks and record each chemical's specific gravity, viscosity and oxidation state.

Facility ID: ______________

Date: ______________

Analyst: ______________

Quality Control: ______________

Chemical	CAS #	Water Solubility (mg/l)	Oxidation State	Specific Gravity	Viscosity a/ (centipoise)	Vapor Pressure (mm Hg)	Henry's Law Constant (atm-m3/mol)	Koc	log Kow	Half-Life (Days)			
										GW	SW	Soil	Air
Arsenic	7440-38-2	NA b/	+3	5.717	NA	0	NA	NA	NA	PERS c/	PERS	PERS	5
Tetrachloroethylene	127-18-4	150	NA d/	1.6227	1.844	178	0.026	364	2.6	NA	1-30	NA e/	47
Acrilonitrile	75-05-8	1.0E+6	NA	.7857	.345	74	4.0E-6	2.2	-0.34	NA	7	NA	390
Toluene	100-38-3	535	NA	.8669	.59	28.1	0.0064	300	2.73	NA	.17	NA	63

a/ At 20° C.

b/ Solubilities for metals are not in Exhibit C-1 because they are very dependent on site-specific conditions (i.e., the anions surrounding the metal and the metal's oxidation state).

c/ Chemical is persistent and consequently does not degrade (all metals are assumed to be infinitely persistent in soil and water).

d/ Oxidation states are important only for metals and inorganics.

e/ Currently not available.

ASSUMPTIONS:

List all major assumptions made in the development of data for this worksheet:

A brief description of the relevance of each property to potential chemical release, transport, and fate is given below. Additional discussion of these parameters is available in numerous references.[6] [7] [8] [9]

Water solubility is the maximum concentration of a chemical that dissolves in pure water at a specific temperature. The solubility of inorganic chemicals varies widely depending on the nature of the chemical and the environment it is found in. The pH (acidity/alkalinity) and Eh (redox potential) will affect solubility by influencing the nature of the soluble species that are dissolved. Changes in redox potential can cause the release or removal of inorganics to the soil or sediments. The type and concentration of complexing agents present in water will also influence solubility. Organic compounds will also have variable solubilities which can also be affected by temperature, pH, and the composition of the solution. Solubilities range from less than 1 ppb to greater than 100,000 ppm, with most of Appendix VIII organic compounds falling between 1 and 100,000 ppm.[10]

Water solubility is a critical property affecting environmental fate.[11] Solubility is one of the factors that controls leachate strength and migration of chemicals from waste sites (along with sorption potential, soil type, and water infiltration). Highly soluble chemicals can be rapidly leached from wastes and contaminated soil and are generally mobile in ground water. Solubility affects "leachability" into both ground water and surface water, and highly soluble compounds are usually less strongly adsorbed (and are thus more mobile) in both ground and surface water. Solubility, along with several other factors, also affects volatilization from water -- in general, high solubility is associated with low volatilization rates.[12] Chemicals with high solubilities also tend to be more readily biodegradable than those with lower solubilities.[13] Water solubility is especially important in the evaluation of aquatic exposure pathways.

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[6] E.E. Kenaga and C.A.I. Goring, "Relationship Between Water Solubility, Soil-Sorption, Octanol/Water Partitioning, and Bioconcentration of Chemicals in Biota," in J.G. Eaton, P.R. Parrish, and A.C. Hendricks, Aquatic Toxicology (Philadelphia: American Society for Testing and Materials, 1978).

[7] W.J. Lyman, W.F. Reehl, and D.H. Rosenblatt, Handbook of Chemical Property Estimation Methods (New York: McGraw-Hill, 1982).

[8] D.W. Nelson, D.E. Elrich, K.K. Tangi, D.M. Kral, and S.L. Hawkins, eds., Chemical Mobility and Reactivity in Soil Systems (Proceedings) (Madison: American Society of Agronomy, The Soil Science Society of America, 1983).

[9] A.W. Maki, K.L. Dickson, and J. Cairns, eds., Biotransformation and Fate of Chemicals in Aquatic Environments (Washington, D.C.: American Society for Microbiology, 1980).

[10] W.J. Lyman, "Solubility in Water," in Lyman, et al., Handbook of Chemical Property Estimation Methods (New York: McGraw-Hill, 1982).

[11] R.E. Menzer and J.O. Nelson, "Water and Soil Pollutants," in J. Doull, C.D. Klaassen, and M.D. Amdur, Toxicology (New York: MacMillan, 1980).

Some chemicals may be present at a site at concentrations higher than their water solubilities. This situation can arise in the case of non-aqueous phase liquids (e.g., organic liquids that are not dissolved in water and that are less dense than water, thereby forming a second liquid layer, which can float on top of an aqueous phase). Contaminants may be more soluble in these liquids and be dissolved in the non-aqueous phase at concentrations higher than their water solubilities.

Vapor pressure and **Henry's law constant** are two constants useful for predicting the extent to which a chemical will be released into the air, and thus are important in evaluating air exposure pathways. Vapor pressure is a relative measure of the volatility of a chemical in its pure state.[14] Vapor pressures of liquids range from 0.001 to 760 torr (mm Hg), with solids ranging down to 10^{-7} torr.[15] Vapor pressure is an important determinant of the rate of vaporization of a chemical, but other factors, including temperature and wind speed, degree of adsorption, water solubility, and soil conditions, are also important. Vapor pressure is most directly relevant to exposure pathways involving chemical releases to air from spills or contaminated surface soils. The Henry's law constant, which combines vapor pressure with solubility and molecular weight, is more appropriate for estimating releases to air from contaminated water (e.g., surface water) and should be used to evaluate chemicals for which this type of exposure pathway is expected.

The **organic carbon partition coefficient** (K_{oc}) is a measure of relative sorption potential for organic chemicals and is a significant environmental fate determinant for all exposure pathways, especially aqueous pathways. K_{oc} indicates the tendency of an organic chemical to be adsorbed to soil.[16] K_{oc} is expressed as the ratio of the amount of chemical adsorbed per unit weight of soil organic carbon content to the chemical concentration in solution at equilibrium. Therefore:

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[12] R.E. Menzer and J.O. Nelson, "Water and Soil Pollutants," in J. Doull, C.D. Klaassen, and M.D. Amdur, Toxicology (New York: MacMillan, 1980).

[13] W.J. Lyman, "Solubility in Water," in Lyman, et al., Handbook of Chemical Property Estimation Methods (New York: McGraw-Hill, 1982).

[14] H.M. Jaber, W.R. Mabey, A.T. Liu, T.W. Chow, H.C. Johnson, T. Mill, R.T. Padall, and J.S. Winterle, Data Acquisition for Environmental Transport and Fate Screening (Washington, D.C.: Office of Health Assessment, U.S. Environmental Protection Agency, 1984).

[15] C.F. Grain, "Vapor Pressure," in Lyman, et al., Handbook of Chemical Property Estimation Methods (New York: McGraw-Hill, 1982).

[16] W.J. Lyman, "Adsorption Coefficient for Soils and Sediments," in Lyman, et al., Handbook of Chemical Property Estimation Methods (New York: McGraw-Hill, 1982).

$$K_{oc} = \frac{\text{mg adsorbed/kg organic carbon}}{\text{mg dissolved/liter solution}}$$

The normal range of K_{oc} values is from 1 to 10^7, with higher values indicating greater sorption potential.[17J] Many other partition coefficients exist (e.g., organic matter coefficient (K_{om}), soil/water distribution coefficient (K_d)), but K_{oc} was selected for use as an indicator of soil adsorption because it is chemical-specific and for organics is directly related to soil and sediment sorption, both of which are significant chemical fate processes at many sites. For inorganics, some other parameter such as the distribution coefficient for a specific soil type (K_d) or the maximum exchangeable mass may be a better measure of relative adsorption potential.

The significance and interpretation of K_{oc} varies with different exposure pathways. For ground water, low K_{oc} values indicate that sorption of the chemical to the soil organic matter is not a fate-controlling process and, therefore, faster leaching from the waste source into an aquifer and relatively rapid transport through the aquifer (i.e., limited retardation of the chemical) occurs. K_{oc} is directly proportional to the retardation factor, which is used in many ground-water transport models. Therefore, high mobility (low K_{oc}) chemicals generally would be of more concern than low mobility (high K_{oc}) chemicals. The effectiveness of using K_{oc} to predict mobility is dependent on the fraction of organic carbon in the soil in contact with the chemical.

For surface water pathways, K_{oc} also has several significant implications. A high K_{oc} indicates tight bonding of a chemical to sediments high in organic carbon, which means that less of the chemical will be dissolved in site runoff, but also implies that runoff of contaminated particles may occur over a longer time period. At some sites, direct recharge of surface water by ground water is important; in these situations, because of ground-water mobility considerations, chemicals with high K_{oc} values are of relatively lower concern. The K_{oc} value also indicates the relative amount of sediment adsorption in surface waters.

The **octanol-water partition coefficient**, K_{ow}, is often used to estimate the extent to which a chemical will partition from water into lipid-containing parts of organisms (e.g., animal fat) and thereby bioaccumulate. K_{ow} is often expressed in log units (i.e., log K_{ow}).

[17J] W.J. Lyman, "Adsorption Coefficient for Soils and Sediments," in Lyman, et al., Handbook of Chemical Property Estimation Methods (New York: McGraw-Hill, 1982).

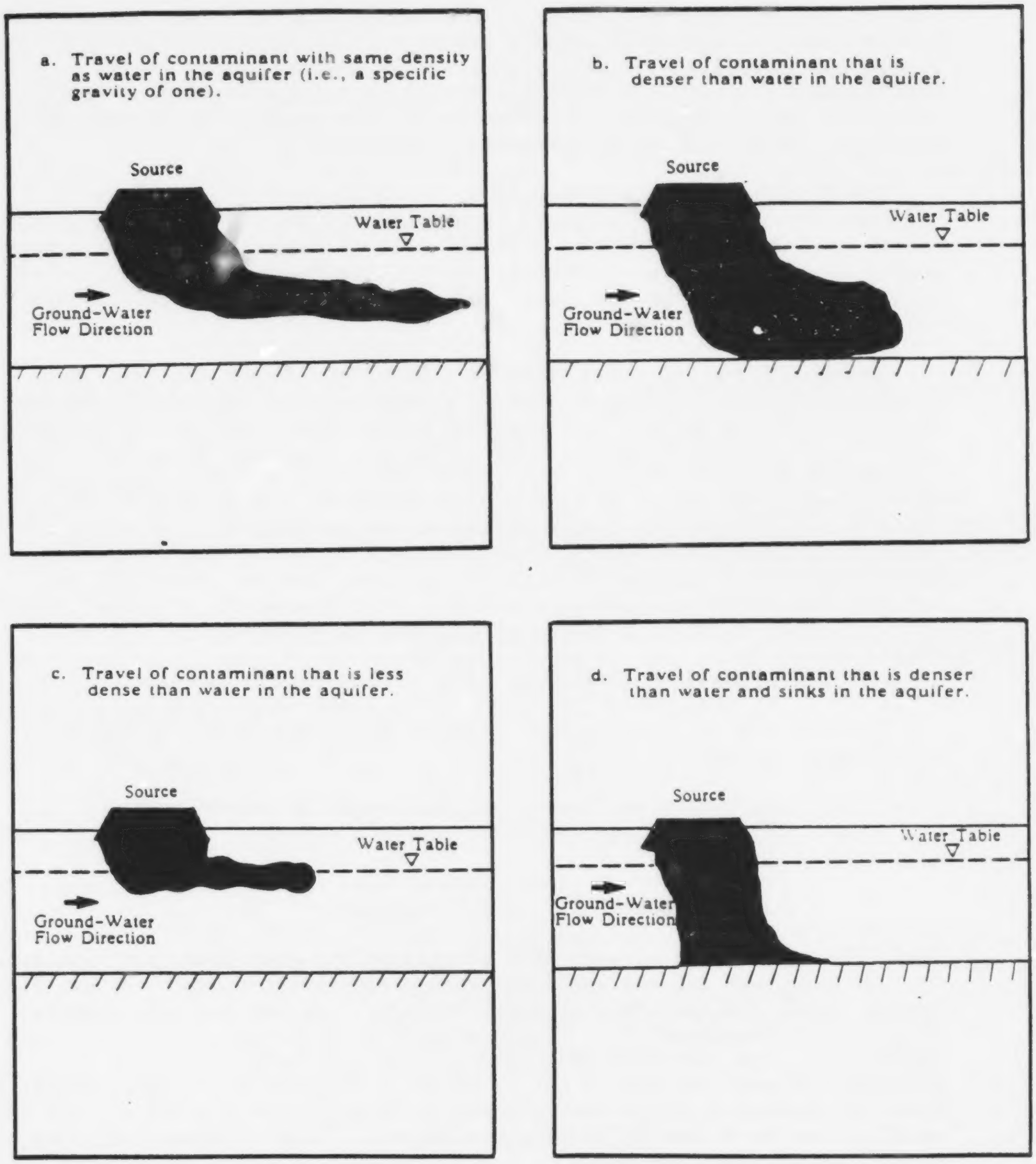
Compounds with a low log K_{ow} (e.g., less than 1) tend to have small sediment/soil partition coefficients, and relatively high water solubilities. A high log K_{ow} indicates that the chemical will partition into the sediment or soil, and have a low water solubility. Once a chemical enters surface water, however, a high log K_{ow} may be of great concern because it indicates a tendency to bioaccumulate. If aquatic food chain pathways are possibly significant, this implication of K_{ow} should be considered.

Persistence is a measure of how long a chemical will exist in a given environmental medium, obviously a critical factor in assessing exposure potential. Important removal processes are phase transfer (e.g., water to air, soil to water), chemical transformation (e.g., hydrolysis, photolysis), and biological transformation (e.g., biodegradation). Available persistence data are given in Exhibit C-2 as ranges of overall half-lives (i.e., due to all removal processes) in ground water and surface water. If half-life values from other sources are used, the applicant must determine whether they represent overall disappearance rates or whether they correspond to a specific removal mechanism. The rate at which removal processes occur will depend on the specific environmental conditions. The disappearance rate will act as a measure of how quickly a chemical is removed from the environmental medium. Half-lives of chemicals vary from seconds to thousands of years. Small half-lives generally indicate a lower level of concern, although degradation products may have a higher toxicity or environmental mobility than the original chemical. The literature may be a potential source of degradation product data; however, the applicability of these data to the variance demonstration will depend on the degradation process that can be expected for the site being analyzed.

Specific gravity is the ratio of the density of a substance to the density of pure water. Consequently, if a substance is denser than water, its specific gravity is greater than one, and the substance will tend to sink in water. If the substance is less dense than water, it has a specific gravity less than one, and the substance will float on water. The specific gravity of a substance, therefore, is a measure of how the substance behaves when placed in water. This principle can be applied to contaminants as they pass through the unsaturated zone and come into contact with the ground-water table. A contaminant with a specific gravity less than one will float on top of the water table and, if it has a low solubility, will mix very little with the ground water. If a contaminant has a specific gravity greater than one, it will sink toward the bottom of an aquifer. A liquid contaminant with a specific gravity of one will tend to mix with the ground water. Exhibit 2-2 illustrates the effect of specific gravity on the movement of contaminants in ground water.

In a uniform geologic setting, the greater the specific gravity of the contaminant is above one, the greater the downward migration of that contaminant will be and the slower the contaminant will travel in relation to the velocity of the ground-water flow. Generally, the majority of chemical contaminants travel in the direction of ground-water flow at a velocity somewhat less than that of the ground water. The prediction of contaminant migration requires accurate knowledge of the specific gravity and solubility of the contaminant solution.

Exhibit 2-2
TRANSPORT OF CONTAMINANTS WITH DIFFERENT SPECIFIC GRAVITIES



a. Travel of contaminant with same density as water in the aquifer (i.e., a specific gravity of one).

b. Travel of contaminant that is denser than water in the aquifer.

c. Travel of contaminant that is less dense than water in the aquifer.

d. Travel of contaminant that is denser than water and sinks in the aquifer.

Source: R. Allan Freeze and John A. Cherry, *Groundwater*, (New Jersey: Prentice-Hall, Inc., 1979), p. 390

Viscosity of a fluid is the property of resistance to relative motion and shear deformation during flow. The more viscous the fluid, the greater the shear stress and, thus, the resistance to flow. Viscosity is affected by temperature; the higher the temperature, the lower the viscosity and the easier it will be for a fluid to move through the pores in a medium. Water is the primary viscosity standard. Hydrocarbon liquids such as hexane are less viscous, while heavy lubrication oil is highly viscous. The viscosity of a contaminant will partially control the rate of movement or migration. More viscous contaminants will not move as easily through porous media. Consideration of contaminant viscosity, if it differs significantly from water viscosity, in conjunction with other applicable chemical properties may be necessary for prediction of contaminant migration.

The **oxidation state** of some metals (as determined by the number of valence- or outershell-electrons) is affected by the oxidation-reduction (redox) potential of ground or surface water or soils. While metals such as sodium usually exhibit only one oxidation state (e.g., sodium +1), others, such as chromium, manganese, iron, and copper (transition metals), have multiple oxidation states.

Changes in the oxidation state of a metal may affect its relative solubility or insolubility in water. A soluble metal species may become insoluble and precipitate out of ground water, thus altering its transport or migration with changes in the redox potential. A change in oxidation state can also affect the toxicity of a contaminant. For example, chromium is the most toxic and mobile in an oxidation state of +6. Under acidic or reducing conditions, chromium can change oxidation states from +6 to +3. The +3 chromium is less toxic and generally immobile in ground water because it will readily combine with dissolved anionic species, such as hydroxide, and precipitate to form insoluble compounds. This phenomenon is common to most inorganics and to all transition metals (as listed above).

2.1.2 Toxicological Properties

Toxicological properties that indicate potential hazard to exposed individuals include:

- toxicity class (potential carcinogen or noncarcinogen);
- EPA qualitative weight-of-evidence category (potential carcinogens);
- EPA severity-of-effect rating value (noncarcinogens); and
- indicator chemical toxicity constant.

These properties have already been identified for most chemicals (see Appendix C). On Worksheet 2-2 the applicant should record the toxicity class, EPA rating value, and indicator chemical toxicity constant for each chemical identified in Worksheet 2-1. These toxicological properties can be found in Appendix C. The indicator chemical toxicity constants, which can be found in Exhibits C-3 and C-5, should not be confused with the risk characterization toxicity constants, which can be found in Exhibits C-4 and C-6 and are to be used in Chapter 6 (Health Effects Evaluation). Each of these toxicological properties is described below.

WORKSHEET 2-2

INDICATOR CHEMICAL TOXICITY INFORMATION

Facility ID: ______
Date: ______
Analyst: ______
Quality Control: ______

INSTRUCTIONS:

1. Record compounds from Worksheet 2-1, then refer to Exhibit C-3 and C-5 and note whether they are classified as potential carcinogen (PC) or noncarcinogen (NC) or both.
2. Record the rating value (noncarcinogens, Exhibit C-5) or EPA category (potential carcinogens, Exhibit C-4) for each compound in each class. If there are route-specific differences (i.e., oral or inhalation), record both values.
3. Refer to Exhibits C-3 and C-5 and record the toxicity constant value associated with water.

Chemical	Toxicologic Class (PC, NC)	Rating Value/EPA Category a/	Water Toxicity Constant (1/mg)
Arsenic	PC	A	4.07
	NC	9	18
Tetrachloroethylene	PC	B2	.0089
	NC	7 (oral) 10 (inhalation)	.0096
Acetonitrile	NC	NA	NA
Toluene	NC	7 (oral) 7 (inhalation)	.0052

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a/ Rating value is for severity-of-effect for noncarcinogens, range is 1(low) to 10(high); EPA category is a qualitative weight-of-evidence designation for potential carcinogens; explanation of the categories is presented in Exhibit 2-2. Information taken from Appendix C.

ASSUMPTIONS:

List all the major assumptions made in developing the data for this worksheet:

Toxicity class for a chemical indicates whether the chemical is a potential carcinogen and/or noncarcinogen. The designation of the class or classes is based on experimental evidence, structure activity relationships, and epidemiological evidence.

Exhibits C-3 and C-5 list potential carcinogens and noncarcinogens, respectively. Consequently, an applicant must review both lists to identify the toxicity class(es) for a particular chemical.

Generally, compounds either not listed in Appendix C or with insufficient data for indicator scoring should be classified as unknown under toxicologic class in Worksheet 2-2. These substances should be listed in the application to provide an indication of the uncertainty associated with omitted chemicals and to assist regional and headquarter's personnel in identifying data gaps. If the applicant has reason to believe that these compounds may be significant at his/her site, he/she may contact the Environmental Criteria and Assessment Office (ECAO), U.S. EPA, 26 W. St. Clair Street, Cincinnati, Ohio 45268, for guidance in determining the toxicity class and estimating the necessary toxicity constants.

EPA qualitative weight-of-evidence category indicates the quality and quantity of data underlying a chemical's designation as a potential human carcinogen. The categories of evidence for human carcinogenicity include sufficient, limited, and inadequate. Exhibit D-2 (Appendix D) presents the EPA qualitative weight-of-evidence categories for potential carcinogens. Weights of evidence for specific chemicals are provided in Exhibit C-4 (Appendix C).

EPA rating value identifies the severity of effect for noncarcinogens. The value ranges from 1 to 10, where one represents minor biochemical changes and 10 represents death or pronounced life-shortening. The EPA rating values for specific chemicals are presented in Exhibit C-5 (Appendix C). The effects associated with each rating value are provided in Exhibit D-1 (Appendix D).

Toxicity constants for indicator chemical selection (T values) are derived for two types of toxic effects (carcinogenicity and other chronic effects). Indicator chemical toxicity constants for noncarcinogens (Tn) are derived from the minimum effective dose (MED) for chronic effects, a severity-of-effect factor (i.e., EPA rating value), and standard factors for body weight and oral intake (e.g., 70 kg body weight, 2 liters/day of drinking water). Indicator chemical toxicity constants for potential carcinogens (Tc) are based on the dose (i.e., effective dose) at which a 10 percent incremental carcinogenic response is observed (ED_{10}) and the same standard intake and body weight factors used for the MED. Values for indicator chemical toxicity constants for a number of compounds are given in Exhibits C-3 and C-5. Appendix D describes in detail the methods used for calculating the toxicity constants in Appendix C. The data base for this procedure is adopted from the supporting documentation for the Superfund Reportable Quantities rulemaking.[1]

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[1] EPA, ECAO. Summary Data Tables for Chronic Noncarcinogenic Effects, 1984. [Note: Prepared during Reportable Quantity adjustment process]; and EPA, OHEA. Methodology for Evaluating Reportable Quantity Adjustments Pursuant to CERCLA Section 102, External Review Draft, OHEA-C-073, 1986.

2.2 SELECTION OF INDICATOR CHEMICALS

The purpose of this section is to present a methodology to select indicator chemicals. This procedure was adapted from the Superfund Public Health Evaluation Manual.[19] The indicator chemical selection procedure described here is designed to identify the "highest risk" chemicals at a site so that the risk assessment is focused on the chemicals of greatest concern. Two separate sets of indicator chemicals will be selected: one for the human health effects evaluation and another for the environmental impact evaluation. The indicator chemical selection process is designed for tank systems with large numbers of chemicals where consideration of all physical, chemical, and concentration information at one time is too cumbersome. If only a moderate number of chemicals are present within the tank system(s), all toxicity, chemical, and physical factors may be considered simultaneously. In general, if less than 10 to 15 chemicals are handled within the tank system(s), this indicator chemical selection step is not necessary (i.e., all the chemicals should be considered indicator chemicals). In such cases, the applicant should proceed to Section 2.3 and evaluate the potential release volumes and chemical release masses for all of the chemicals handled within the tank system(s).

For tank systems that contain a large number of chemical substances, conducting a risk assessment that includes all the identified chemicals may be unnecessary. In these cases, the risk-based variance can be based on selected indicator chemicals that pose the greatest potential risk to human health and the environment at or near a facility. Such indicator chemicals must be chosen carefully so that they represent the most toxic, highly concentrated, mobile, and persistent chemicals stored and/or treated in the tank systems at the site (i.e., the "highest risk" chemicals).

Two important factors for ranking chemicals in the indicator chemical selection process are their measured concentrations within the tank systems and their toxicities. Additional factors to be considered include physical and chemical parameters related to environmental mobility and persistence. If, after completing the procedures described in this section, any chemicals considered to be potentially significant are not selected, professional judgment should be used to include them. It is not intended that the indicator chemical selection process exclude any chemical that may potentially cause significant human or environmental harm. Rather, the intent of the process is to ensure that all chemicals that may potentially pose a significant risk to human health and the environment are addressed and to focus the risk assessment on the chemicals of primary concern.

The procedure to select indicator chemicals consists of three steps. A flowchart of these steps is presented in Exhibit 2-3. The procedures for carrying out the three selection steps are described in the remainder of this section. The initial list of chemicals presented in Worksheet 2-1 will be shortened using additional factors to develop a final indicator list. In the

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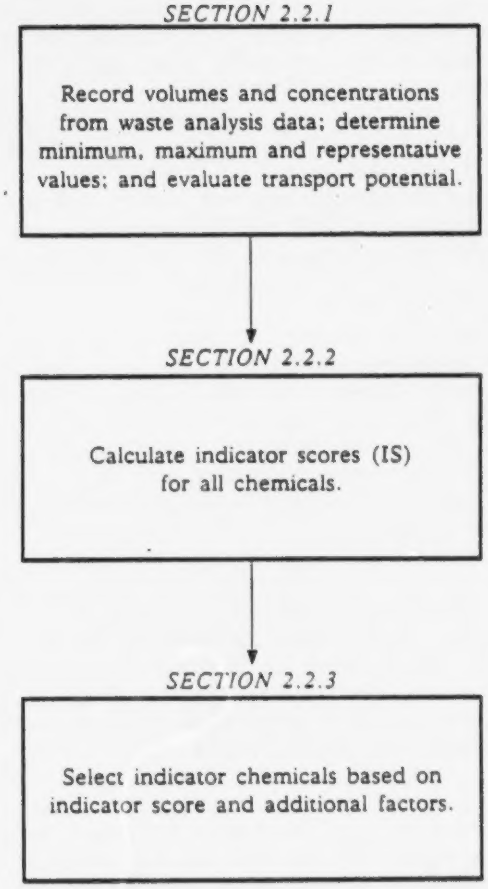
[19] EPA, Superfund Public Health Evaluation Manual, Office of Emergency and Remedial Response, EPA 540/1-86/060, October 1986, pp. 19-34.

Exhibit 2-3

OVERVIEW OF PROCEDURE FOR SELECTING INDICATOR CHEMICALS


SECTION 2.2.1
Record volumes and concentrations from waste analysis data; determine minimum, maximum and representative values; and evaluate transport potential.
SECTION 2.2.2
Calculate indicator scores (IS) for all chemicals.
SECTION 2.2.3
Select indicator chemicals based on indicator score and additional factors.

examples on the worksheets accompanying this section, only four chemicals are used. An applicant with four chemicals would not need to select a set of indicator chemicals (all would be considered); however, for illustrative purposes, we only present four.

2.2.1 Identification of Representative Chemical Concentrations

A chemical may exist at different concentrations in one or more tank systems or components. For example, chloroform may be present in two different tank systems for which the variance would apply. To facilitate the risk assessment process, it may be helpful to summarize these concentrations with one concentration. Worksheet 2-3 illustrates a procedure for calculating the overall concentration of a chemical based on the concentrations of the chemical in different tank systems.

For each chemical, the applicant should list on Worksheet 2-3 the tank systems where the chemical is stored or treated, the annual throughput, and chemical concentrations within the tank system. The chemical concentrations should be based on a detailed chemical and physical analysis of the waste contained in the tank systems.[20] To determine the representative chemical concentration, it may be appropriate to use a geometric mean[21] of all of the samples as the most representative concentration, or it may be more appropriate to choose a concentration that reflects a time trend occurring at the site. The applicant should calculate the minimum, maximum, and representative annual mass of the chemical handled by the tank system by multiplying the annual tank throughput by each concentration. The applicant should then calculate the total annual throughput and minimum, maximum, and representative annual mass of chemical by summing the annual throughputs and masses, respectively. The overall minimum, maximum, and representative chemical concentration within the tank systems is the ratio of the total chemical mass to the total annual throughput of the tank systems containing the chemical.

Worksheet 2-4 should be used to list all hazardous constituents handled in the tank systems included in the variance application and handled in tank systems that were previously granted a variance. Worksheet 2-4 should also be

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[20] Most owners or operators who treat, store, or dispose of any hazardous waste must obtain a detailed chemical and physical analysis of a representative sample of the waste (40 CFR 264.13). Owners and operators seeking a variance who are exempt from the waste analysis requirement must conduct this analysis for the variance. Applicants may refer to the following documents for guidance on analyzing the contents of their tanks: EPA, Test Methods for Evaluating Solid Waste, SW-846, Office of Water and Waste Management, 1982; or EPA, Methods of Chemical Analysis of Water and Waste, EPA-600/4-79-020, March 1979.

[21] The geometric mean (antilog $[\ln X_1 + \ln X_2 + \ldots + \ln X_n]/n$) is considered to be more representative than an arithmetic mean for evaluating environmental data. See: Robert B. Dean, "Use of Log-Normal Statistics in Environmental Monitoring," in Chemistry in Water Use: Volume I, William J. Cooper, ed. (Ann Arbor: Ann Arbor Science Publishers, Inc., 1981), pp. 245-258.

WORKSHEET 2-3

CALCULATION OF OVERALL CHEMICAL CONCENTRATIONS IN TANK SYSTEMS

Facility ID: ______________
Date: ______________
Analyst: ______________
Quality Control: ______________

INSTRUCTIONS:

1. Identify the chemicals in the tank systems (use one worksheet for each chemical).
2. Identify tank systems that contain each chemical.
3. Identify annual throughput of each tank system in liters (to convert from gallons to liters multiply by 3.7854).
4. Identify chemical concentrations (minimum, maximum, representative) in each tank system.
5. For each tank system, calculate the annual mass of chemical handled by the tank (the annual mass equals the product of the annual throughput and concentration, divided by 1,000,000 to convert to kilograms.)
6. Calculate total annual throughput of all tanks and total annual mass of chemical handled in all tank systems.
7. Calculate the overall chemical concentration within the tank systems (divide total annual mass of chemical by total annual throughput and multiply by 1,000,000 to convert to milligrams).

Chemical: Toluene

		Chemical Concentration In Tank System (mg/l)			Annual Mass of Chemical Handled in Tank System (kg)		
Tank System ID	Annual Throughput (liters)	Minimum	Maximum	Representative	Minimum	Maximum	Representative
A-1	75,708	.7	6.0	4.0	.0530	.454	.303
A-2	283,905	.9	10.0	6.0	.255	2.839	1.703
A-3	151,416	1.0	11.0	6.0	.151	1.666	.908
Total:	511,029				.460	4.959	2.915

Overall chemical concentration in tank systems: .9 9.7 5.7

ASSUMPTIONS:

List all major assumptions made in developing the data for this worksheet:

WORKSHEET 2-4

SCORING FOR INDICATOR CHEMICAL SELECTION:
OVERALL CONCENTRATIONS, Koc, AND log Kow VALUES

Facility ID: ______________

Date: ______________

Analyst: ______________

Quality Control: ______________

INSTRUCTIONS:

1. Write down each chemical found within the tank system and its Koc and log Kow values (from Worksheet 2-1) (use additional worksheets if necessary).
2. If more than 20 chemicals are listed, identify those with the ten highest Koc values with an H and those with the ten lowest Koc values with an L. In addition, identify those with the ten highest log Kow values with an H* and those with the ten lowest log Kow values with an L*.
3. Record an overall minimum, maximum, and "representative" concentration from Worksheet 2-3 and enter it; indicate in footnotes the basis of the representative value (e.g., Waste Analysis Report).
4. Record indicator chemical toxicity constant value from Worksheet 2-2.
5. Record the freshwater chronic water quality criteria from Exhibit 7-2. If not available state NA.

			Overall Chemical Concentration (mg/l)				Indicator Chemical Toxicity Constant (l/mg)		
Chemical	Koc Value	log Kow Value	Minimum	Maximum	Representative a/	Reference b/	NC	PC	Fresh Chronic Criteria (mg/l)
Arsenic	--	NA	<.010	.46	.075	B,112	18	4.07	190
Tetrachloroethylene	364	2.6	BDL c/	67	3.2	A,18	0.0096	0.0089	840
Acetonitrile	2.2	-0.34	<.005	.05	.006	B,112	NA	-	NA
Toluene	300	2.73	.9	9.7	5.7	A,18	0.0052	-	NA

a/ Mean of reported values used as representative concentration for all tank systems used to store or treat the chemical; zero used for all values reported as below detection limit.

b/ A = 1986 Annual Facility Report, B = Waste Analysis. Page numbers follow document designation. Documents included as appendix.

c/ BDL = below detection limits.

ASSUMPTIONS:

List all the major assumptions made in developing the data for this worksheet; also indicate any concerns about the waste analysis data.

used to summarize the chemical concentration information developed in Worksheet 2-3. In addition, the applicant should record on this worksheet the K_{oc} value, log K_{ow} value, and toxicity constant for each chemical from Worksheet 2-2. The applicant should indicate on Worksheet 2-4 the basis for the representative concentration chosen and note any assumptions or additional information required to use this information. If there are concerns about use of these concentrations, they should be noted. For example, if a highly toxic chemical will be present in the tank in the future, it should be included. If a chemical is considered sufficiently important, it may be chosen as an indicator chemical regardless of its concentration.

2.2.2 Calculation of Indicator Scores for all Chemicals

This section is divided into two subsections. The first describes the process for calculating the indicator scores that will be used in selecting the chemicals to be considered for the human health effects evaluation (health-based indicator scores, or ISH). The second subsection presents the procedure for calculating indicator scores that will be used in choosing the chemicals to be considered in the environmental impact evaluation (environmental quality-based indicator scores, or ISE).

Health-Based Indicator Scores. The following algorithm is used to determine the health-based indicator score for each chemical within the tank systems:

$$ISH_i = (C_i \bullet T_i)$$

where

ISH_i = health-based indicator score for chemical i (dimensionless),

C_i = overall concentration of chemical i within the tank systems at the facility based on waste analysis data (units must be mg/l in water), and

T_i = an indicator chemical toxicity constant for chemical i (units are the inverse of above concentration units).

Concentration values used in this equation for a given chemical should be representative of all available data. Indicator chemical toxicity constant units are the inverse of their respective concentration units so that indicator scores (C•T) will always be dimensionless. Essentially, the indicator score is a ratio between measured concentration and a toxicity-based concentration benchmark that is used to rank the chemicals. The use of these toxicity constants for selection of indicator chemicals within hazardous waste tank systems will be reconsidered if additional toxicological information becomes available for ranking the toxicity of a large number of chemicals.

The next task is to compare the ISH values of the various chemicals. Because of probable differences in dose-response mechanisms (non-threshold vs. threshold), potential carcinogens (PCs) and noncarcinogens (NCs) are scored and compared independently. **Indicator scores for carcinogens and noncarcinogens are not on comparable scales and should never be compared.**

The applicant should list all potential carcinogens on Worksheet 2-5 and all noncarcinogens on Worksheet 2-6. The applicant should then calculate C times T (i.e., C•T) for each chemical and the associated overall minimum, maximum, and representative concentrations. The chemicals on Worksheets 2-5 and 2-6 should be ranked separately on the basis of the indicator scores. If a chemical is designated as both a PC and NC, the indicator scoring procedures should be completed for it in both toxicity classes.

Environmental Quality-Based Indicator Scores. A slightly different equation is required to calculate environmental quality-based indicator scores:

$$ISE_i = (C_i/Q_i)$$

where

ISE_i = the environmental quality-based indicator score for chemical i (dimensionless),

C_i = overall concentrations of chemical i within the tank systems at the facility based on waste analysis data (units in mg/l), and

Q_i = freshwater chronic water quality criterion for chemical i (units in mg/l).

The same overall concentrations that were used to calculate health-based indicator scores should be used here. The freshwater chronic water quality criteria (Q) for a number of chemicals are provided in Exhibit 7-2. On Worksheet 2-7, the applicant should list all chemicals contained in the tank systems. For each chemical the applicant should calculate the ratio of the overall minimum, maximum,and representative concentrations to the freshwater chronic water quality criterion for the chemical. If no criterion is available for the chemical, the applicants should state "data not available." Based on the indicator scores, the applicant should rank the chemicals from highest to lowest environmental quality-based indicator score.

2.2.3 Selection of Final Indicator Chemicals

The applicant should use Worksheet 2-8 to prepare an initial list of indicator chemicals to be considered for use in the human health effects evaluation and Worksheet 2-9 to prepare an initial list of indicator chemicals to potentially be used for the the environmental impact evaluation. The final lists of indicator chemicals (one for the health effects evaluation and one for the environmental impact evaluation) will be selected from these initial lists of indicator chemicals. In most cases the initial list (and, subsequently, the final selection) should be based on representative concentrations, although indicator scores based on minimum or maximum concentrations may be used to modify the selection.

On Worksheet 2-8 the applicant should record, in rank order according to the health-based indicator score values, the top-scoring 15 to 20 chemicals from both Worksheet 2-5 (potential carcinogenic effects) and Worksheet 2-6 (noncarcinogenic effects). This initial list of indicator chemicals on Worksheet 2-8 should then be compared to the chemicals identified with either

WORKSHEET 2-5

SCORING FOR INDICATOR CHEMICAL SELECTION:
CALCULATION OF INDICATOR SCORE VALUES AND TENTATIVE RANK FOR CARCINOGENIC EFFECTS

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

INSTRUCTIONS:

1. List all of the chemicals to be considered as potential carcinogens.
2. Calculate overall concentration times toxicity (CT) values using the information from Worksheets 2-1 and 2-2. Calculate a CT based on the overall minimum, maximum, and representative concentrations.
3. Rank the compounds based on their minimum, maximum, and representative indicator score values. Also, enter their EPA weight-of-evidence category in the final column.

Chemical	Indicator Score Value			Tentative Rank			Weight of Evidence
	Minimum	Maximum	Representative	Maximum	Minimum	Representative	
Arsenic	0.0407	1.87	0.3053	1	1	1	A
Tetrachloroethylene	0	0.5936	0.0284	2	2	2	B2

ASSUMPTIONS:

List all major assumptions made in developing the data for this worksheet:

WORKSHEET 2-6

SCORING FOR INDICATOR CHEMICAL SELECTION:
CALCULATION OF INDICATOR SCORE VALUES AND TENTATIVE RANK FOR NONCARCINOGENIC EFFECTS

Facility ID: __________
Date: __________
Analyst: __________
Quality Control: __________

INSTRUCTIONS:

1. List all of the chemicals to be considered for noncarcinogenic effects.
2. Calculate overall concentration times toxicity (CI) values using the information from Worksheets 2-1 and 2-2. Calculate CI values based on the overall minimum, maximum, and representative concentrations.
3. Rank the compounds based on their minimum, maximum, and representative indicator score values. Also enter the severity-of-effects rating value(s) in the final column.

Chemical	Indicator Score Value			Tentative Rank			Rating Value(s)	
	Minimum	Maximum	Representative	Minimum	Maximum	Representative	Oral	Inhalation
Arsenic	0.18	8.28	0.135	1	1	1	9	-
Tetrachloroethylene	0	0.6445	0.0308	3	2	2	7	10
Acetonitrile	NA	NA	NA	-	-	-	-	-
Toluene	0.0047	0.0504	0.0296	2	3	3	7	7

ASSUMPTIONS:

List all major assumptions made in developing the data for this worksheet:

WORKSHEET 2-7

SCORING FOR INDICATOR CHEMICAL SELECTION: CALCULATION OF INDICATOR SCORE VALUES AND TENTATIVE RANK FOR ENVIRONMENTAL EFFECTS

INSTRUCTIONS:

1. List all of the chemicals to be considered for environmental effects.
2. Calculate indicator scores by dividing overall concentration by fresh water chronic water quality criteria using the information from Worksheets 2-1 and 2-2. Calculate water quality indicator score values based on overall minimum, maximum, and representative concentrations.
3. Rank the compounds based on their minimum, maximum, and representative indicator score values.

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Chemical	Indicator Score Value			Tentative Rank		
	Minimum	Maximum	Representative	Minimum	Maximum	Representative
Arsenic	1.0E-4	.0024	.0004	1	2	2
Tetrachloroethylene	0	0.8798	0.0038	2	1	1
Acetonitrile	-	-	-	-	-	-
Toluene	-	-	-	-	-	-

ASSUMPTIONS:

List all major assumptions made in developing the data for this worksheet:

WORKSHEET 2-8

SCORING FOR INDICATOR CHEMICAL SELECTION FOR HUMAN HEALTH EFFECTS EVALUATION: EVALUATION OF EXPOSURE FACTORS AND FINAL CHEMICAL SELECTION

Facility ID: ______________

Date: ______________

Analyst: ______________

Quality Control: ______________

INSTRUCTIONS:

1. List the top 15 to 20 PC and NC chemicals based on health-based indicator score (ISH) values, giving their ISH values and their ranking (use additional sheets).
2. Refer to Worksheet 2-1 and record each chemical's solubility, vapor pressure, Henry's law constant, Koc, and half-lives in ground water, surface water, soil, and air.
3. Select the final indicator chemicals. Use your judgment -- if a compound has a high water solubility and a long half-life, yet is ranked lower than a compound with minimal water solubility and a short half-life, you may wish to move it up in the ranking (refer to Section 2.2.3 for additional guidance on the final selection).
4. Document any changes in ranking made because of exposure factors.
5. In the last column indicate with a "+" those chemicals that have been selected as indicator chemicals (IC).

Chemical	ISH Values a/		Ranking		Water Solubility (mg/l)	Vapor Pressure (mm Hg)	Henry's Law Constant (atm-m3/mole)	Koc	Half-Life (Days)				IC b/
	PC	NC	PC	NC					GW	SW	Soil	Air	
Arsenic	0.305	0.135	1	1	NA	0	NA	-	PERS	PERS	PERS	5	+
Tetrachloroethylene	0.028	0.031	2	2	150	178	0.026	364	NA	1-30	NA	47	+
Acetonitrile	NA	-	NA	-	1,000,000	74	.00004	2.2	NA	7	NA	390	+
Toluene	NA	0.030	NA	3	535	28.1	0.0064	300	NA	.17	NA	63	+

a/ Based on overall representative concentrations.

b/ Because only four chemicals are used in this example, all four are chosen as indicator chemicals. If there had been 15 or more chemicals, the top 10 to 15 chemicals would have been selected as indicator chemicals.

ASSUMPTIONS:

List all major assumptions made in the development of data for this worksheet:

an H (or H*) or an L (or L*) on Worksheet 2-1. H indicates one of 10 chemicals with the highest K_{oc} values (H* refers to K_{ow}), and L indicates one of 10 chemicals with the lowest K_{oc} values (L* refers to K_{ow}). If an important exposure scenario at the site (see Chapter 5) involves consumption of contaminated fish and none of the 10 chemicals designated with an H* (i.e., a high K_{ow} value) made it onto the initial indicator list on Worksheet 2-8, the applicant should consider placing one or more of them onto that list. If exposure via ground-water contamination is a concern and none of the 10 chemicals designated with an L (i.e., a low K_{oc}) made it onto the initial indicator list on Worksheet 2-8, the applicant should consider enlarging the initial indicator list to include one or more of these chemicals. Some chemicals may not have been possible to score due to lack of data. These chemicals should still be considered for the initial indicator chemical list. They may be selected for the final list based on other properties.

On Worksheet 2-9, the applicant should list the top scoring 15 to 20 chemicals from Worksheet 2-7 based on decreasing environmental quality-based indicator score. Again, some chemicals may not have been possible to score due to lack of data. These chemicals should still be considered for the initial indicator chemical list. They may be selected for the final list based on other properties.

Final selection of indicator chemicals is not based solely on a numerical ranking algorithm or set of precise decision rules. Instead, there are several chemical-specific factors to consider, plus a few general selection rules. The initial factor to consider is the relative indicator scores (ISH and ISE) of the chemicals. The indicator scores, based in part on concentrations at the site, have already been used to rank chemicals for the two initial indicator chemical lists on Worksheets 2-8 and 2-9. In general, higher ranking chemicals (based on representative ISH values) should be selected from the human health effects evaluation initial indicator chemical list over lower ranking chemicals within the same toxicologic class (PC or NC). This rule can be modified, however, based on the additional selection factors discussed below. Because ISH values for PC and NC are not directly comparable, the ISH value is not relevant to a selection of the relative number of PC and NC chemicals. Therefore, the applicant should include several top-ranked (by ISH) PC and NC as indicator chemicals for the human health effects evaluation.

There is no predetermined number of indicator chemicals appropriate for all sites; for each list (i.e., for the human health effects evaluation and the environmental impact evaluation), between 10 and 15 chemicals would be a manageable number and may be sufficient for most facilities. However, if a very large number of chemicals are present within the tank systems, it may be wise to select more as indicators. The number and identity of indicator chemicals selected is a site-specific decision that must be made and documented for the tank systems.

Although the indicator score is the initial selection factor, several additional factors are also important. These factors include five chemical properties related to exposure potential: water solubility, vapor pressure,

WORKSHEET 2-9

SCORING FOR INDICATOR CHEMICAL SELECTION FOR ENVIRONMENTAL IMPACT EVALUATION: EVALUATION OF EXPOSURE FACTORS AND FINAL CHEMICAL SELECTION

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

INSTRUCTIONS:

1. List the top 15 to 20 chemicals according to environmental quality-based indicator score (ISE) values, giving their ISE values and their ranking. Also list chemicals that could not be scored.
2. Refer to Worksheet 2-1 and record each chemical's solubility, vapor pressure, Henry's law constant, Koc, and half-lives in ground water (GW), surface water (SW), soil, and air.
3. Select the final indicator chemicals based on the guidelines presented in Section 2.2.3. Use your judgment -- if a compound has a high water solubility and a long half-life, yet is ranked lower than a compound with minimal water solubility and a short half-life, you may wish to move it up in the ranking.
4. Document any changes in ranking made because of exposure factors.
5. In the last column indicate with a "+" those chemicals that have been selected as indicator chemicals (IC).

Chemical	ISE Values[a/]	Ranking	Water Solubility (mg/l)	Vapor Pressure (mm Hg)	Henry's Law Constant (atm-m3/mole)	Koc	Half-Life (Days) GW	SW	Soil	Air	IC [b/]
Tetrachloroethylene	0.0038	1	150	178	0.026	364	NA	1-30	NA	47	+
Arsenic	0.004	2	NA	0	NA	-	PERS	PERS	PERS	5	+
Acetonitrile	NA	NA	1,000,000	74	.000004	2.2	NA	7	NA	390	+
Toluene	NA	NA	535	28.1	0.0064	300	NA	.17	NA	63	+

a/ Based on representative concentrations.

b/ In this example, all chemicals are selected; however, an applicant following this procedure would usually have more than 15 chemicals to consider, and therefore the top 10 to 15 would be selected.

ASSUMPTIONS:

List all major assumptions made in the development of data for this worksheet:

Henry's law constant, organic carbon partition coefficient (K_{oc}),[22] and persistence in various media. Extremes of any of these factors for a chemical found in a tank system may produce a high future exposure potential and may warrant inclusion of the chemical in the final list of indicator chemicals despite a low indicator score value. Values for these factors were specified in Worksheet 2-1. The applicant should record appropriate values for the initial indicator chemicals on Worksheet 2-7 for the human health effects evaluation list and on Worksheet 2-9 for the environmental impact evaluation list.

Clearly, other chemical properties could affect exposures and risks at a specific site. However, to limit the amount of data to be collected and considered, the characterization of the physical and chemical properties of the chemicals focuses on the five properties listed above. These properties are important, but not exclusive, determinants of environmental transport and fate (e.g., density and viscosity are additional important properties). Some of the properties have different implications for different exposure pathways. As a result, consideration of the potential exposure pathways at a site is necessary when applying physical/chemical factors in the selection process. Refer to Section 2.1 for a brief description of the relevance of each property to potential chemical release, transport, and fate.

Using the information provided below and the discussion in Sections 2.1 and 2.2 as guidance, the applicant should make the final selection of 10 to 15 indicator chemicals for each list. Starting with the initial chemical lists compiled in Worksheets 2-8 and 2-9, the applicant should consider indicator score values and relevant additional factors in the final selection process. The applicant should indicate on Worksheets 2-8 and 2-9 final selections and the rationale for each. If toxic organics and inorganics are both present in the tank systems, at least one of each should be included on both of the final lists of indicator chemicals. Chemicals on the preliminary indicators list with sufficient evidence of human carcinogenicity (EPA Group A) or with limited human evidence and sufficient animal evidence (EPA Group B1) should generally be selected as final indicators for the human health effects evaluation (Worksheet 2-8), unless there are convincing reasons to do otherwise, such as if a chemical has a relatively low concentration and indicator score compared to other chemicals. For chemicals with similar ISH values, those with a stronger weight-of-evidence should usually be selected. On Worksheet 2-9, chemicals with the highest log Kow values should be included in the final list, since bioaccumulation is a significant environmental impact.

By following the procedures described in this chapter, the applicant should have selected a subset of the chemicals present in the tank systems to serve as indicator chemicals for the human health effects evaluation and the environmental impact evaluation. The procedure has been structured to favor the selection of those chemicals that pose the greatest potential risks and, therefore, should serve as indicator chemicals. There are many components of the selection procedure that require individual judgment. Care must be taken to apply the general principles set forth in each step in a consistent manner so that the final scores are comparable. **The scores developed here are used only for relative ranking and have no meaning outside the context of this procedure.** They should not be considered as a quantitative measure of a chemical's toxicity or exposure potential.

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[22] As discussed previously (see Section 2.1), a chemical's K_{oc} is being used as an estimator of environmental mobility. K_{oc} is considered to account for the possibility of substances leaching out of the soil and being introduced into surface and ground water. In general, chemicals with low K_{oc} values will tend to be leachable from soil and mobile in ground water. Also, chemicals with high K_{oc} values tend to have correspondingly high bioconcentration factors.

2.3 POTENTIAL WORST-CASE RELEASE VOLUMES AND INDICATOR CHEMICAL RELEASE MASSES

For each tank system component for which a variance is being sought, the applicant must assume a release incident and corresponding release volume to be used in assessing the potential risks to human health and the environment. This section recommends specific worst-case release volumes for different tank system components and describes how they should be used to calculate release masses for the indicator chemicals. The transport of these release masses can then be modeled and exposure point concentrations of the indicator chemicals can be calculated (see Chapter 5). Subsection 2.3.1 discusses the methodology for determining worst-case potential release volumes and Subsection 2.3.2 discusses the methodology for calculating chemical release masses.

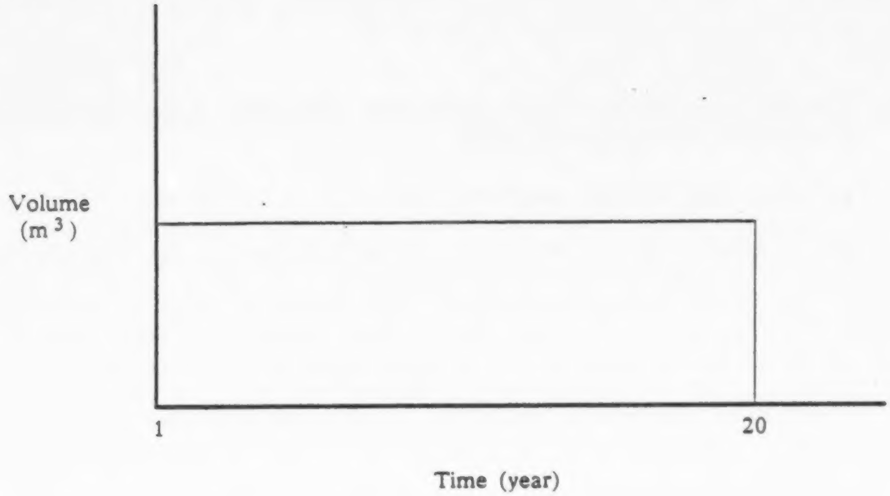
2.3.1 Determination of Worst-Case Potential Release Volumes

When applying for a variance, the applicant must use reasonable worst-case potential release volumes associated with the tank systems or tank system components for which a variance is being sought. Releases should be assumed to occur over a 20-year time horizon, which is intended to simulate the remaining operating life of the tank system. Although 20 years may overestimate the remaining operating life of a tank system component in some instances, estimates must be conservative in order to demonstrate no potential hazard to human health and the environment. In situations where the applicant can demonstrate to the Regional Administrator that the tank is going to operate for less than 20 years, this shorter time horizon may be used. The annual series of releases is termed a release volume profile, and is illustrated in Exhibit 2-4 for tank system components in contact with the soil (steady-state releases), and aboveground tanks (catastrophic releases).

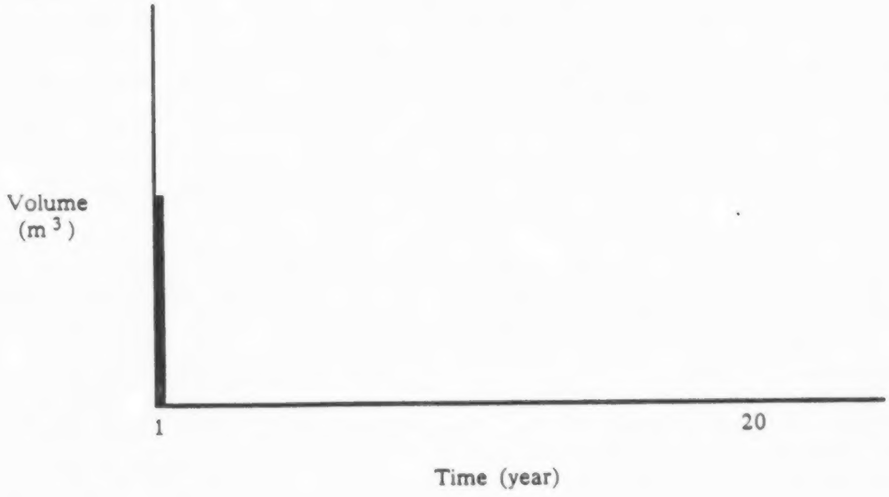
The worst-case potential release volumes for a particular tank system component (i.e., a tank or pipe) basically depend on whether the tank system component can be visually inspected on all surfaces for leaks. Because underground, inground, and onground tank systems have components that are in contact with the soil, complete external visual inspection is not possible. Consequently, such tank system components can conceivably leak (e.g., due to a corrosion hole or seam failure) some percentage of their throughput for long periods of time without the leak being detected. For underground, inground, and onground tank system components, the applicant should therefore assume that 25 percent of the annual throughput for a component could leak annually.

Exhibit 2-4
HYPOTHETICAL RELEASE VOLUME PROFILES

Steady-State:



Catastrophic:



The 25 percent cut off is based on professional judgment and the assumption that a tank owner/operator does not suspect a tank leak unless the tank is less than 75 percent full at the time the tank is emptied.

Aboveground tank system components, unlike underground, inground, and onground components, can be visually inspected on all surfaces (daily visual inspections are required by the regulations (40 CFR 264.195(b) (51 Federal Register 25476, July 14, 1986))) and, therefore, are not likely to leak over a long period of time. Thus, the worst-case potential release volume for an aboveground tank system component is typically a release that occurs between daily inspections. For an aboveground tank, the applicant should assume that the full tank volume is released due to a catastrophic failure in the first year of the modeled time horizon. The probability of a catastrophic release is sufficiently small that it would be unrealistic to assume more than one during the operating life of the tank. For aboveground ancillary equipment, such as piping and pumps, the applicant should assume that a volume equivalent to the maximum daily throughput is released annually for the operating life of the tank system. The potential for leaks from aboveground ancillary equipment is sufficiently high to justify the need to consider releases on an annual basis.

The variance applicant should not use release volumes smaller than those presented here. The release volumes that should be used for individual components are summarized below:

Component Location	Component	Release Volume
Underground, inground, onground	All components	25 percent of the annual tank system throughput annually for 20 years
Aboveground	Tank	Tank capacity released in model year one
Aboveground	Ancillary equipment	Maximum daily throughput annually for 20 years

To obtain the total annual release volumes (i.e., release profile) for a tank system, the release volumes for the individual components of the system must, in most cases, be summed. An exception to this rule is for components in a tank system that are located underground, inground, or onground. The release volumes for all of these components in a tank system should not be added; i.e., the total release volume for all underground, inground, and onground components in a tank system should be assumed to be 25 percent of the annual throughput annually. By not adding release volumes for these components, multiple counting of release volumes is avoided. For example, consider a tank system that consists of an aboveground tank of 5,000 gallons, fed by a run of aboveground piping, and connected to an underground tank of 5,000 gallons by underground piping. The maximum daily throughput for the aboveground piping is 100 gallons and the annual throughput for the tank system is 25,000 gallons. For the aboveground piping, the release volume is 100 gallons per year. For the aboveground tank, the release volume is 5,000 gallons in the first year. For the underground piping and the underground tank the total release volume is 6,250 gallons (.25 x 25,000) annually. For the whole tank system 11,350 gallons are released in the first year (100 + 5,000 + 6,250), and 6,350 gallons (100 + 6,250) are released annually thereafter.

The applicant should complete Worksheet 2-10 in developing the release volume profiles. On this worksheet, the applicant should list each tank system and the tank system components for which a variance is being sought or for which a variance was previously granted. For each component, the tank volume, annual throughput, and maximum daily throughput should be provided when applicable (e.g., tank volume does not apply to piping). For each component, the annual release volumes should then be determined according to the guidelines stated at the beginning of this section. Finally, the applicant should sum the release volumes for the components and record the total release volumes for each tank system. Note that separate worksheets should be used for different tank system clusters, if it is necessary to cluster tank systems for modeling purposes.[23]

2.3.2 Calculation of Indicator Chemical Release Masses

The identification of indicator chemicals and corresponding indicator chemical concentrations (i.e., minimum, maximum, and representative) for each tank system was discussed in Section 2.2 (the chemicals and concentrations should be listed in Worksheet 2-3). This information must be combined with the release volume profiles to obtain a release mass profile for each indicator chemical. The applicant should use Worksheets 2-11, 2-12, and 2-13, for the minimum, maximum, and representative indicator chemical concentrations, respectively, to develop the indicator chemical release mass profiles. On these worksheets, the applicant should list the indicator chemical, the tank systems that contain the indicator chemical, the corresponding indicator chemical concentrations (see Worksheet 2-3), and the corresponding release volumes from chemicals Worksheet 2-10. The applicant should multiply the indicator chemical concentrations by the release volume profile to obtain the indicator chemical release mass profile for each tank system. The applicant should then add the indicator chemical release mass profiles for each tank system to obtain the total release mass profile for the indicator chemical. If tank systems were clustered when assessing release volume profiles, the same clusters should be maintained for determining release mass profiles. The applicant must exercise care when specifying indicator chemical concentrations

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[23] In some situations, tank systems may be physically separated by relatively large distances such that releases from them would have different exposure points, or it would not be realistic to model the transport of the summed tank releases to the same exposure point. In such a situation, tank systems should be clustered into groups in which the tanks are close enough together to allow for realistic modeling of the transport of releases to exposure points. A space is provided on the worksheet to identify the tank system cluster, if necessary.

WORKSHEET 2-10

RELEASE VOLUME PROFILES ASSOCIATED WITH EACH TANK SYSTEM

INSTRUCTIONS:

1. List each tank system, its components for which a variance is being sought or for which a variance was previously granted, the locations of the components (i.e., aboveground, onground, inground, underground), the tank volume, annual throughput (not necessary for aboveground components), and maximum daily throughput (only necessary for aboveground ancillary equipment).
2. Fill in the annual release volumes for the components according to the rules specified in the text.
3. For each tank system, sum the release volumes of the components and record the result. Note, however, that release volumes for underground, inground, and onground components in the same tank system should not be added. Only the release volumes from one of these components should be counted in the total to avoid double counting.

Facility ID: ________

Cluster: ________

Date: ________

Analyst: ________

Quality Control: ________

Tank System	Tank System Component	Component Location	Tank Volume (gallons)	Annual Throughput (gallons)	Maximum Daily Throughput (gallons)	Annual Release Volume (gallons) Year 1	Annual Release Volume (gallons) Years 2-20 (per year)
A-1	tank	underground	5,000	20,000	n.a.	5,000	5,000
	pipe	underground	n.a.	20,000	n.a.	5,000	5,000
					Total	5,000	5,000
A-2	tank	onground	25,000	75,000	n.a.	18,750	18,750
	pipe	onground	n.a.	75,000	n.a.	18,750	18,750
					Total	18,750	18,750
A-3	tank	aboveground	10,000	40,000	n.a.	10,000	0
	pipe	aboveground	n.a.	40,000	175	175	175
	pump	aboveground	n.a.	40,000	175	175	175
					Total	10,350	350
					Total		

WORKSHEET 2-11

RELEASE MASS PROFILES ASSOCIATED WITH EACH INDICATOR CHEMICAL: MINIMUM CONCENTRATION

INSTRUCTIONS:

1. Fill out a separate worksheet for each indicator chemical.
2. Identify the tank system(s) that contain the indicator chemical.
3. List the minimum concentration within the tank systems from Worksheet 2-3.
4. List the corresponding annual release volumes from Worksheet 2-8 for each tank system.
5. Calculate for the indicator chemical the mass released (in kilograms) for each tank system (annual mass released equals the annual release volume (in gallons) multiplied by 3.7854 to convert to liters, multiplied by the minimum concentration (in mg/liter), multiplied by 10^{-6} to convert to kilograms).
6. Calculate the total chemical mass released by summing the masses for the individual tank systems.

Facility ID: __________

Cluster: __________

Date: __________

Analyst: __________

Quality Control: __________

Indicator Chemical: Toluene

Tank System	Minimum Concentration (mg/liter)	Annual Volume Released Year 1	Annual Volume Released Years 2-20 (per year)	Annual Mass Released (kg) Year 1	Annual Mass Released (kg) Years 2-20 (per year)
A-1	.7	5,000	5,000	0.0132	0.0132
A-2	.9	18,750	18,750	0.0639	0.0639
A-3	1.0	10,350	350	0.0392	0.0013
			TOTAL	0.1163	0.0784

WORKSHEET 2-12

RELEASE MASS PROFILES ASSOCIATED WITH EACH INDICATOR CHEMICAL: MAXIMUM CONCENTRATION

INSTRUCTIONS:

1. Fill out a separate worksheet for each indicator chemical.
2. Identify the tank system(s) that contain the indicator chemical.
3. List the maximum concentration within the tank systems from Worksheet 2-3.
4. List the corresponding annual release volumes from Worksheet 2-8 for each tank system.
5. Calculate for the indicator chemical the mass released (in kilograms) for each tank system (annual mass released equals the annual release volume (in gallons) multiplied by 3.7854 to convert to liters, multiplied by the maximum concentration (in mg/liter), multiplied by 10^{-6} to convert to kilograms).
6. Calculate the total chemical mass released by summing the masses for the individual tank systems.

Facility ID: __________

Cluster: __________

Date: __________

Analyst: __________

Quality Control: __________

Indicator Chemical: Toluene

Tank System	Maximum Concentration (mg/liter)	Annual Volume Released (gallons)		Annual Mass Released (kg)	
		Year 1	Years 2-20 (per year)	Year 1	Years 2-20 (per year)
A-1	6.0	5,000	5,000	0.1136	0.1136
A-2	10.0	18,750	18,750	0.7098	0.7098
A-3	11.0	10,350	350	0.4310	0.0416
			TOTAL	1.2544	0.8650

WORKSHEET 2-13

RELEASE MASS PROFILES ASSOCIATED WITH EACH INDICATOR CHEMICAL: REPRESENTATIVE CONCENTRATION

INSTRUCTIONS:

1. Fill out a separate worksheet for each indicator chemical.
2. Identify the tank system(s) that contain the indicator chemical.
3. List the representative concentration within the tank systems from Worksheet 2-3.
4. List the corresponding annual release volumes from Worksheet 2-8 for each tank system.
5. Calculate for the indicator chemical the mass released (in kilograms) for each tank system (annual mass released equals the annual release volume (in gallons) multiplied by 3.7854 to convert to liters, multiplied by the representative bound concentration (in mg/liter), multiplied by 10^{-6} to convert to kilograms).
6. Calculate the total chemical mass released by summing the masses for the individual tank systems.

Facility ID: ____________

Cluster: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Indicator Chemical: Toluene

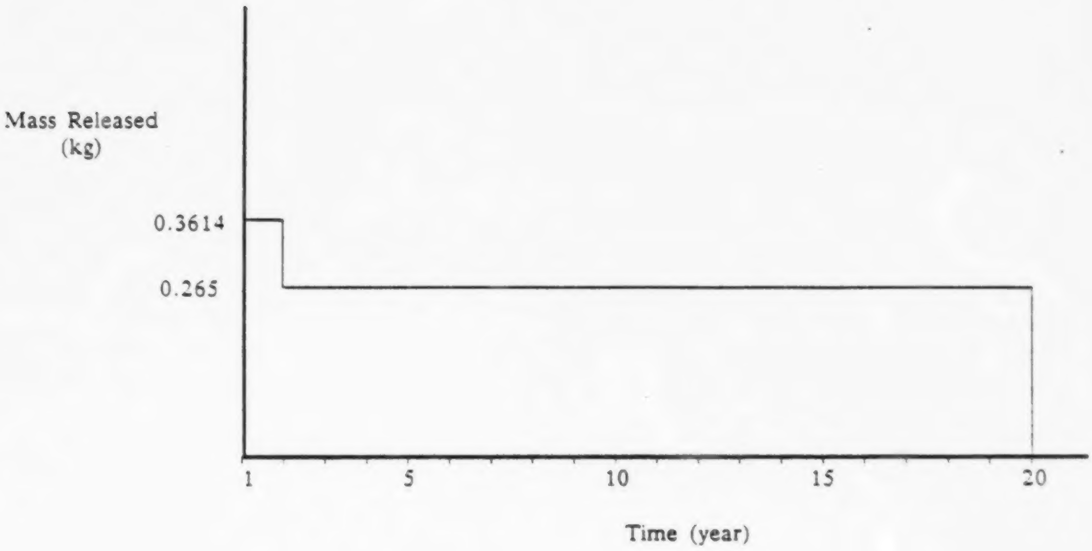
Tank System	Representative Concentration (mg/liter)	Annual Volume Released (gallons)		Annual Mass Released (kg)	
		Year 1	Years 2-20 (per year)	Year 1	Years 2-20 (per year)
A-1	4.0	5,000	5,000	0.0757	0.0757
A-2	6.0	18,750	18,750	0.4259	0.4259
A-3	6.0	10,350	350	0.2351	0.0079
			TOTAL	0.7367	0.5095

for treatment tank systems in which the chemical concentrations differ among tanks in a series. In such cases, the applicant must use the indicator chemical concentration at the earliest point in the treatment system (i.e., inflow to the first tank) for which a variance is being sought.

A simple example may be helpful to illustrate the procedure. Consider a facility with a 5,000 gallon aboveground tank and a 10,000 gallon underground tank, both of which are filled and emptied four times a year (resulting in annual throughputs of 20,000 gallons and 40,000 gallons, respectively). The indicator chemical for the aboveground tank is benzene at a concentration of 5 mg/l. The indicator chemical for the underground tank is also benzene at a concentration of 7 mg/l. The release volume profile for the aboveground tank consists of 5000 gallons (18,927 liters) released in year one. The release volume profile for the underground tank is 10,000 gallons (37,854 liters) per year for 20 years. For benzene, the release mass profile for the aboveground tank is (5 mg/l)(18,927 liters)(1 kg/10^6 mg) = 0.0946 kg in year one, while for the underground tank it is (7 mg/l)(37,854 liters)(1 kg/10^6 mg) = 0.265 kg annually for 20 years. The sum of the two release mass profiles for benzene is 0.0946 + 0.265 = 0.3614 kg of benzene released in the first year and 0.265 kg of benzene released annually for 19 years thereafter. The release mass profile for the indicator chemical benzene is illustrated in Exhibit 2-5.

The release mass profiles developed for each indicator chemical should be used in modeling the transport of the indicator chemicals and the calculation of concentrations at exposure points. These steps are discussed in Chapter 5 of this technical resource document.

Exhibit 2-5
HYPOTHETICAL RELEASE MASS PROFILE FOR BENZENE



CHAPTER 3

HYDROGEOLOGIC CHARACTERIZATION

As stated in the revised hazardous waste tank regulations, the Regional Administrator will consider the potential adverse effects on ground water, surface water, and land quality, taking into account the hydrogeologic characteristics of the facility and surrounding land in deciding whether to grant a variance from the requirements of secondary containment.[1] This chapter is intended to assist owners/operators in identifying relevant geologic or hydrogeologic information for potential inclusion in a variance. This information will have the following two uses:

- provide general geologic and hydrogeologic data associated with the site that is important or necessary in evaluating the potential migration of hazardous waste from the tank system to ground or surface water; and
- provide the hydrogeologic information (e.g., hydraulic conductivity, porosity) necessary for performing an environmental fate analysis as described in Chapter 5, Exposure Point Concentrations.

In general, a description of the hydrogeologic framework of an area should include a discussion of the following factors:

- important climatic aspects of site area (e.g., precipitation and infiltration);
- structural attitude and distribution of bedrock and overlying strata;
- chemical and physical properties of underlying strata (soil and rock), including lithology, mineralogy, and hydraulic properties;
- soil characteristics, including soil type and distribution, and attenuative properties; and
- ground-water regime, including water table depths, aquifer types, flow paths and rates.

This chapter identifies information that will be necessary to fully and adequately characterize the hydrogeology of a site (and include in an application). This complete characterization will be required for most variance applications. However, if the quality of ground water beneath the site is very poor (i.e., is not a current or potential future source of drinking water), or if an applicant can show that there are no pathways of exposure to ground water (as discussed in Chapter 5), investigative or data gathering efforts can be reduced. These potential situations should be assessed before designing and conducting site-specific hydrogeologic studies. Examples of data reduction that may be possible if either of these situations exist are as follows:

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[1] Section 264.193(g)(2)(i)(B) (51 Federal Register 25475, July 14, 1986).

- extensive subsurface and surficial investigations should not be needed; applicant may be able to present general geologic and hydrogeologic information available from published sources;
- detailed aquifer characterization, including the measurement of hydraulic conductivity and gradients, and the preparation of potentiometric surface maps, etc., should not be needed. It would be necessary to describe any underlying potable aquifer and to show its lack of interconnection with the upper aquifer; and
- the environmental fate analysis (transport modeling) of Section 5.2 and the calculation of parameters for the analysis need not be done.

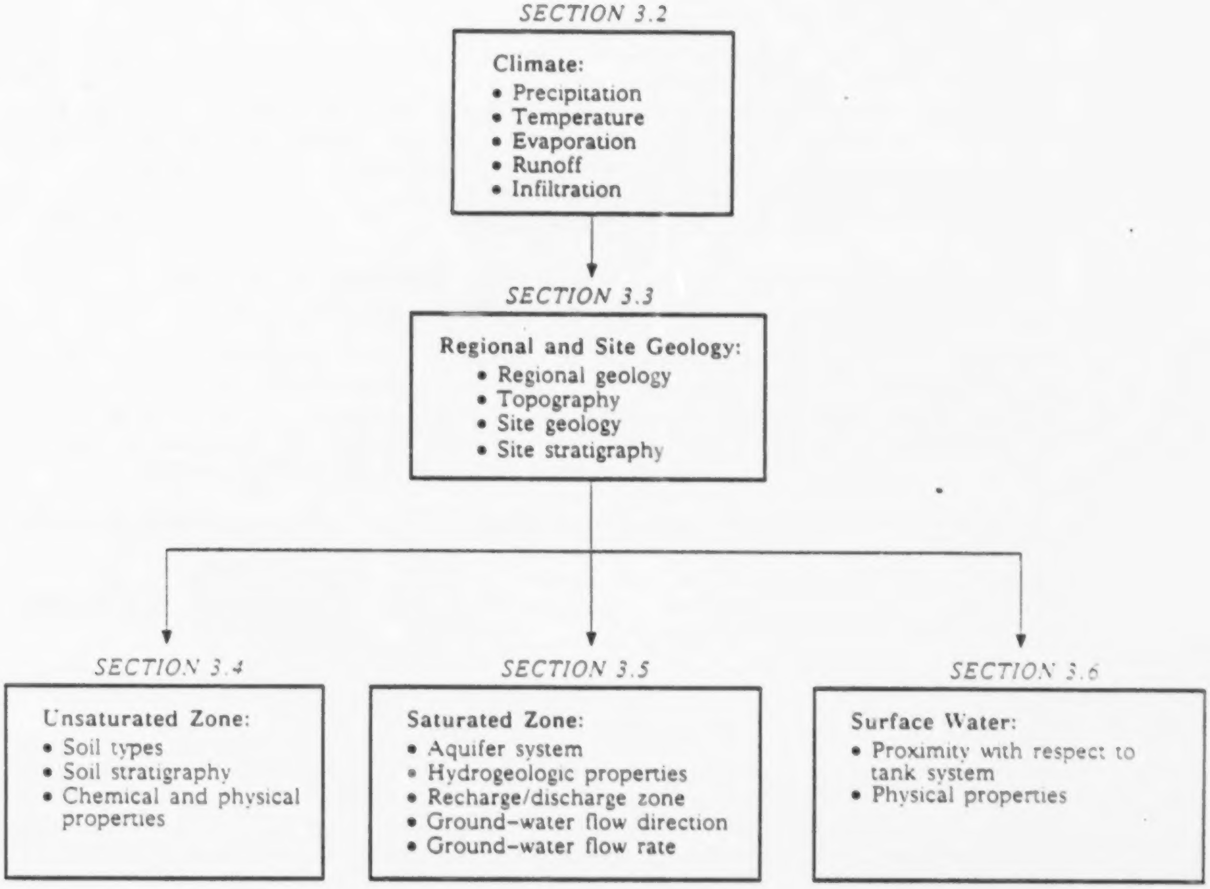
It must be emphasized that the Regional Administrator may require additional information to supplement that which is identified in this chapter for inclusion in a variance application.

This chapter has been divided into six subsections. Section 3.1 summarizes investigative techniques that data gathering efforts, detailed in subsequent subsections, often require. Sections 3.2 through 3.6 are organized around the types of information that are needed to characterize a site-specific hydrogeologic setting. Section 3.2 describes the types of climatic information applicants should identify for assessing the impacts of rainfall patterns. Section 3.3 discusses regional and site-specific data that applicants should present to characterize surface and subsurface geology. Section 3.4 discusses unsaturated zone information, such as soil types, extents, and properties necessary for a hydrogeologic characterization. Section 3.5 describes aspects of the saturated zone that should be assessed in the application, including the aquifer system and hydrogeologic properties, and ground-water flow patterns. Finally, Section 3.6 describes surface water features that should be considered for inclusion in the application. These sections and the types of information they discuss are illustrated in Exhibit 3-1.

While this chapter is intended to give the variance applicant an idea of, and a guide to, the extent of necessary data-gathering efforts, it should not be viewed as a "checklist" for the completeness of an application's hydrogeologic characterization. The exact types and amounts of information that will need to be collected and presented will vary from site to site, e.g., sites with more heterogeneous subsurfaces require more information to characterize the hydrogeology.

Exhibit 3-1

OVERVIEW OF PROCESS TO CHARACTERIZE SITE HYDROGEOLOGY


SECTION 3.2
Climate:
• Precipitation
• Temperature
• Evaporation
• Runoff
• Infiltration
SECTION 3.3
Regional and Site Geology:
• Regional geology
• Topography
• Site geology
• Site stratigraphy
SECTION 3.4
Unsaturated Zone:
• Soil types
• Soil stratigraphy
• Chemical and physical properties
SECTION 3.5
Saturated Zone:
• Aquifer system
• Hydrogeologic properties
• Recharge/discharge zone
• Ground-water flow direction
• Ground-water flow rate
SECTION 3.6
Surface Water:
• Proximity with respect to tank system
• Physical properties

3.1 INVESTIGATIVE TECHNIQUES

This section summarizes the investigative techniques used to collect hydrogeologic data. The purpose of this section is to provide the applicant with an overview of these investigative techniques. It is to be stressed that much of the information identified for characterizing the hydrogeology associated with a site will probably be obtained through extensive laboratory and field investigations, including hydrogeologic, geologic, soil, and water budget surveys, conducted by qualified professionals thoroughly familiar with such methods.

Professionals qualified to perform such investigations span a range of disciplines and include hydrologists, geologists, chemists, geochemists, soil scientists, etc. Because these professionals are familiar with the data necessary to characterize a site and the relevant investigative technqiues, detailed information about hydrogeologic parameters to be included in the variance application, how such parameters are measured or gathered, and their importance in assessing pollution potential, is not provided in this chapter.

Subsequent sections provide a general discussion of the types of data necessary for characterizing a site's hydrogeology and the types of investigative techniques that will likely be used to collect such data. Additional sources of information on investigative techniques can be found in the references of this document.[2] Applicants should realize that the amount of information and investiative efforts needed to characterize a site is extensive. However, such assessments are critical to evaluating the potential migration of hazardous waste released from a tank system.

A variety of investigative techniques are available to collect data for a hydrogeologic characterization. Exhibit 3-2 illustrates a number of techniques that an applicant may employ to perform various aspects of hydrogeologic investigations. Exhibit 3-3 lists some corresponding formats for presenting the resulting data.

The site-specific investigative program should include direct methods (e.g., borings, piezometers, geochemical analysis of soil samples) for determining the site hydrogeology. Indirect methods (e.g, aerial photography, ground penetrating radar, resistivity), especially geophysical studies, also may provide valuable sources of additional information (such as porosity). Thus, an applicant should combine the use of direct and indirect techniques in the investigative program to produce an efficient and complete characterization of the facility site.

In obtaining the information necessary to characterize a site's hydrogeology, the owner/operator should review the available literature of the site area and, when appropriate, use such information in conjunction with site

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[2] Discussions on the characterization of hydrogeology, including geology, aquifers, and ground-water flow paths, can also be found in Chapter 1 of the following document: EPA, RCRA Ground-water Monitoring Technical Enforcement Guidance Document, Office of Solid Waste and Emergency Response, September 1986.

EXHIBIT 3-2

HYDROGEOLOGIC INVESTIGATIVE TECHNIQUES FOR SUBSURFACE INVESTIGATIONS

Definition of Subsurface Materials (Geology):

- Survey of existing geologic information
- Soil borings
- Rock corings
- Material tests (grain size analyses, standard penetration tests, etc.)
- Geophysical well logs (point and lateral resistivity and/or electromagnetic conductance, gamma ray, gamma density, calipher, etc.) [a]
- Surface geophysical surveys (D.C. resistivity, E.M., seismic) [a]
- Aerial photography (fracture trace analysis)
- Detailed lithologic/structural mapping of outcrops and trenches

Identification of Ground-Water Flow Paths (Hydrology), Directions, and Hydraulic Conductivities:

- Installation of piezometers; water level measurements at different depths and locations
- Slug test and/or pump tests
- Tracer studies
- Estimates based on sieve analyses

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[a] These techniques can be used to supplement information gathered from other sources and may be necessary to perform at some sites (e.g., very heterogenous areas).

EXHIBIT 3-3

EXAMPLES OF FORMATS FOR PRESENTING HYDROGEOLOGIC INFORMATION

Narrative description of geology

Geologic cross sections

Geologic or soil maps (plan-view)

Geologic or soil stratigraphic columns or maps

Boring logs or coring logs

Raw data and interpretive analysis of geophysical studies

Raw data and interpretive analysis of material tests

Narrative description of ground water with flow patterns

Water table or potentiometric maps (plan view) with flow lines

Structure contour maps of aquifer and confining layers (plan view)

Raw data and interpretive analysis of slug tests, pump tests, and tracers studies investigations. Such a review may provide a preliminary understanding of the distribution of sediments and rock, general surface water drainage, and ground water. Available materials could include published geologic and topographic maps, hydrogeologic reports, aerial photographs, well drilling logs, and soil surveys. Exhibit 3-4 summarizes the principal sources of such geotechnical data.

A review of available information can also serve to guide the site-specific investigation (e.g., well placement), and can reduce necessary data gathering efforts, i.e., an applicant may be able to present and use data already available. However, the burden of proof is clearly on the applicant to demonstrate that a variance is appropriate. In many situations, the extensive site-specific data described in this chapter will be required to yield an adequate demonstration. Facility owners/operators with on-site tanks and on-site land treatment, storage, or disposal units may have filed a RCRA Part B permit application. If so, much of the data identified for inclusion in the variance application may already be available.

The hydrogeologic data identified in this chapter for inclusion in a variance application should be presented using the methods suggested in this technical document (e.g., tables or maps). Additionally, the variance application should contain a section that compiles and discusses the data and the hydrogeologic setting of the site area as a whole. This section could consist of a hydrogeologic study report (with figures) prepared by geotechnical professionals. Much of the actual data such as well logs and laboratory analyses may lend itself to inclusion in appendices.

3.2 CLIMATIC CHARACTERISTICS

This section describes the types of climatic information that will likely be necessary for identifying the impacts of surrounding rainfall patterns. These impacts will be evaluated with respect to the adverse effects caused by a release of contaminants to surface water and the surrounding land.[13] Additionally, the amount of water that reaches or recharges ground water in an aquifer is determined, in part, by climatic elements -- or more specifically by the amount of precipitation not lost by evaporation (affected by temperature, humidity, and wind) -- and runoff. Thus, these parameters have direct implications to the transport of contaminants and the effects of annual rainfall on contaminant transport through the unsaturated zone should also be assessed.

Impacts of rainfall patterns can be divided into two categories: (1) surface water dilution potential; and (2) runoff potential. Surface water dilution potential affects the ability of nearby surface water to assimilate contaminants and consequently reduce contaminant concentrations. Runoff

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[13] This evaluation is required for considering the potential adverse effects of a release on surface water quality (40 CFR 264.193(g)(2)(iii)(B) (51 Federal Register 25475)) and surrounding land (40 CFR 264.193(g)(2)(iv)(A) (51 Federal Register 25475)).

EXHIBIT 3-4

PRINCIPAL SOURCES OF GEOTECHNICAL DATA

Published Data:

1. USGS[a] surficial geology maps
2. USGS bedrock geology maps
3. USGS hydrological atlases
4. USGS basic data reports
5. State and County geologic and hydrologic maps and reports
6. National and local technical journals, magazines and conference proceedings
7. USSCS[b] soil maps

Unpublished Data:

1. Local test boring and well drilling firms
2. Local and State highway departments
3. Local water departments
4. State well permit records
5. State and Local transportation departments
6. State and Federal Environmental Agencies
7. State and Federal Mining Agencies
8. Army Corps of Engineers
9. Local consulting, construction, and mining companies
10. Geologists, hydrologists, and engineers at local universities
11. Historical records
12. Interviews

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[a] USGS - United States Geological Survey

[b] USSCS - United States Soil Conservation Service

potential affects the transport of contaminants to surface waters and the surrounding land. Surface water dilution will be evaluated concurrently with surface water transport (discussed in Chapter 5, Exposure Point Concentrations). The effects of runoff will be evaluated in the environmental impact evaluation (discussed in Chapter 7, Environmental Impact Evaluation). Consequently, this section discusses the necessary climatic information rather than the assessment of the impacts. Some of the elements that define the climatic characteristics and hydrology of a region include precipitation (i.e., rainfall), temperature, evaporation, runoff, and infiltration. The type of information necessary to assess these phenomena are described below.

Precipitation. Monthly and annual rainfall and snowfall (expressed as its equivalent in rainfall) can be obtained from the National Oceanic and Atmospheric Administration (NOAA), or the National Weather Service. Additionally, daily records are published in "Climatological Data" and "Hourly Precipitation" by the U.S. Environmental Data Service.

Regional precipitation data may be presented and used if they were generated within a reasonably close distance to the tank site (approximately 15 km) and are representative of rainfall conditions at the site. Regional data collected at greater distances from the site should be correlated with available on-site data. The monthly mean and range of these data, the specific time period from which the data came, and the location of the rain gauge(s) in relation to the facility should be provided. Precipitation data can be presented in tables showing monthly and yearly averages over a period of time.

The applicant should submit data on specific storm frequency patterns. The predicted amount of precipitation produced over a 24-hour period by storms with return frequencies of 1, 10, 25, 50 and 100-years should be included. If the site is in a potential flood-plain zone, flood levels in relationship to the site should be identified for these storms. This information should be available from the Federal Insurance Administration (FIA) in the form of maps or other data. If the facility has any special flood prevention devices, (e.g., dikes, berms), these devices could also be shown on a site map. Any special site conditions that affect infiltration and runoff should also be discussed.

Temperature. Ambient air temperature (degree) data can be useful in the general assessment of the climatic setting of a site and may be useful in the assessment of potential volatilization of contaminants. This regional information should be available from similar sources used to obtain precipitation information. Temperature is generally reported as monthly and annual averages over the period of record and is important in assessing evaporation.

Evaporation. Evaporation and transpiration (evapotranspiration) rates (depth of water per unit time) reflect the amount of precipitation returned to the air. Evaporation rates are measured by NOAA, and evapotranspiration rates can be estimated from these data. Evapotranspiration rates can also be obtained through site-studies (using lysimeters), or through published sources if the nearest data set (collected at a gauging station) is representative of the site conditions.

Runoff. Surface runoff is the runoff component of interest for assessing the transport of contaminants over the land surface. Specifically, overland flow (i.e., the part of surface runoff that flows over the land surface toward channels) is of interest. The applicant should identify the potential of overland flow to transport contaminants to land areas of particular interest (e.g., agricultural land) and surface water. This potential depends on the surrounding surface characteristics (e.g., slope, soil type, vegetation, paved areas). If the potential for the transport of contaminants is significant, then the applicant will likely have to conduct a detailed analysis of overland flow (i.e., the identification of the quantity and quality of overland flow). Such an analysis would likely require the use of a runoff simulation model such as the Storm Water Management Model (SWMM).[43]

Infiltration. The maximum rate at which water (precipitation) can enter the soil is the infiltration rate (depth of water per unit time). Infiltration rates (average annual) are important in the determination of the velocity of ground water moving downwards through soil and, hence, in the modeling and determination of contaminant transport rates (see Chapter 5). Records of estimated infiltration rates for an area may be available from sources such as the U.S. Department of Agriculture (Soil Conservation Service). However, it will probably be necessary to estimate this value by taking the average percipitation rate (average annual) and subtracting evapotranspiration and runoff rates (average annual).

3.3 REGIONAL AND SITE GEOLOGY

Applicants will need to present a thorough characterization of surficial and subsurface geology at a site. In order to detail the geology beneath and around the site and, therefore, be able to identify potential pathways of contamination, the applicant (using qualified professionals) must collect and submit extensive information on the geologic properties and features of individual strata beneath and surrounding a site. Subsections 3.3.1 and 3.3.2 discuss the necessary information to characterize regional and site surficial geology and subsurface geology, respectively.

3.3.1 Surficial Geology

This subsection discusses the types of maps and other illustrative exhibits that can be used to characterize on-site and surrounding surficial geology. These maps and the type of illustrated information include:

- regional geologic map used to characterize regional geologic units and structural features;
- topographic maps used to characterize site-specific surficial relief;

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[43] Metcalf and Eddy, Inc., University of Florida, Gainesville, Fla., Water Resource Engineers, Inc., Storm Water Management Model, EPA, Vol. 1, 1971.

- site geologic map used to characterize detailed site-specific surficial geology; and
- aerial photograph used to highlight surficial information (e.g., surrounding vegetation).

These maps are described below.

Regional Geologic Map. The applicant should provide an overview of the regional geology of an area, including the identification of the geologic provinces or setting of the area (e.g., Basin and Range Province), if applicable, and any pertinent geologic history. A large scale plan-view geologic map, available from published sources such as the U.S. Geological Survey, could be included with the application to show geological units and structural features of the region.

Topographic Map. Surficial features may affect ground-water hydrology; therefore, applicants should include a topographic map of the site. The topographic map should be constructed under the supervision of a licensed surveyor, and extend to a distance and scale deemed appropriate by professional judgment (coverage of the area within 100 feet of the site at a scale of 1 inch equal to not more than 200 feet may be adequate.[5]) Contours must be shown on the map. The contour interval should be sufficient to clearly show the pattern of surface water flow in the vicinity of, and from, the hazardous waste tank site. A suggested contour interval is two feet. The map should clearly show the map scale and date, surface water locations (including intermittant streams) (see Section 3.6), orientation of the map, boundaries of the site, and the location and components of the tank.[6] A larger area, regional, topographic map, prepared from published sources, may also be of use in the assessment of the application and should be considered for inclusion.

Site Geologic Map. Detailed surficial geologic information of the site area should be collected and presented on a plan-view geologic map. This map should clearly delineate the tank(s) location and should show structural attitude, distribution, and lithology of surficial bedrock or strata. Faults located on or near the site should be located on the map and (along with geologic information) discussed in the geologic narrative of the application, keeping in mind the potential of such features to act as pathways for the migration of hazardous waste. While published sources will be of use, the level of detail needed for the inclusion of this information will probably need to be obtained via field and mapping surveys. Trenching may be needed to accurately document the location of faults. Professional judgement should be used in determining the area of map coverage.

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[5] As required in a RCRA Part B application, §270.14.

[6] Commenserate with other sections of this manual, this map could show surrounding land uses (see Chapter 4), a wind rose (i.e., prevailing wind speed and direction), locations and illustrations of man-made features (e.g., buildings, on- and off-site wells), and any other potential sources of contamination (e.g., hazardous waste treatment, storage, or disposal units on site).

Aerial Photography. An aerial photograph of the site, if available, should also be considered by the applicant for inclusion in the application. A useful photograph would clearly delineate the site and adjacent off-site features, such as surface water bodies, municipalities, and residences.

3.3.2 Subsurface Geology

This subsection discusses the types of information that should be included in an application to adequately characterize the subsurface geology at and surrounding a site. This information includes:

- regional geologic cross sections used to identify geologic units and structure in the area; and

- stratigraphic maps used to depict the subsurface site stratigraphy.

Methods used to collect this information (e.g., stratigraphic investigations utilizing soil and rock borings) are also discussed.

Regional Geologic Cross Sections. On a regional scale, available generalized geologic cross sections that show subsurface geologic units and structures in the area of the site could be included. These data are intended to show unique regional characteristics and their relationships to the site, and would cover a larger area than the subsurface stratigraphic investigations and resulting maps discussed below.

Stratigraphic Investigations. To assess the geologic properties of strata beneath a site that are likely to influence the migration of contaminated ground water, the variance applicant will need to have geotechnical professionals conduct a thorough subsurface stratigraphic investigation using techniques such as:

- test borings;
- test pit excavations;
- rock coring;
- geophysical surveys; and
- laboratory analysis.[7]

In addition to the types of information discussed here, these investigations will also provide information on site features such as soil and aquifer characteristics (discussed in Sections 3.4 and 3.5). Thus, data collection efforts should coordinate with those discussed in Sections 3.4 and 3.5.

Direct methods (e.g., lithologic analysis) should be employed to identify the lithology and structural characteristics of the subsurface. This identification will involve a soil/rock boring program. In some situations (e.g., shallow aquifer systems), test pits (shallow excavations) may be feasible to use and can reduce data gathering efforts somewhat. These investigations serve to establish the small-scale geology of the area beneath the facility and place it in the context of the geology of the region or locale.

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[7] A detailed description of these techniques and the types of data that can be collected through their use can be found in sources listed in the References section of this document.

Prior to initiating an on-site investigation, available information (e.g., reports, maps, research papers) on local stratigraphy, depositional environment, and tectonic history should be obtained. This information can serve to provide an estimate of the distribution and types of geologic materials likely to be encountered and, thus, assist in the appropriate placement of investigatory boreholes. Obviously, any previous drilled boreholes on or near a site will provide useful data.

Professional judgment must be used in establishing the density of boreholes (i.e., number per unit area) that is needed to characterize the geology beneath a site. Sites with simple underlying geology (i.e., horizontal, thick, unfractured, homogeneous, geologic strata that are continuous across a site and are substantiated by regional geologic information) or where indirect methods (e.g., geophysical surveys) are used to correlate well log data, will normally require relatively few boreholes. Generally, sites with heterogenous stratigraphy (e.g., discontinuous units, or pinchout zones, across the site) may require an increase in the density of boreholes to adequately characterize subsurface units.

The distance between boreholes will depend on site-specific criteria, yet should be close enough so that cross sections constructed from collected data will accurately portray stratigraphy with minimal reliance on inference. After examining initial well logs, it may become evident that additional boreholes will be necessary to completely characterize the subsurface stratigraphy. The need for additional boreholes is a common occurrence since the majority of hydrogeologic settings are complex. Data and observations derived from initial boreholes may be used to guide the placement of future ones. The depth of boreholes will also be site-specific and will depend on the aquifer system present at the site (as discussed in Section 3.5) and the extent of significant hydrogeologic units within the system and below it.

Borehole samples should be collected for each significant stratigraphic contact and formation, especially any confining layers. Continuous cores should be taken initially to ascertain the presence and distribution of small- and large-scale permeable layers and to obtain stratigraphic control. Once stratigraphic control is established, samples can be taken at regular (e.g., five-foot) intervals substituting for continuous cores. After completion of the sampling program, boreholes should be sealed with material at least an order of magnitude less permeable than the surrounding soil/sediment/rock in order to reduce the number of potential contaminant pathways.

Collected samples should be logged in the field by a qualified geologic professional. Drilling logs and field records should be prepared detailing the following information:

- gross petrography (e.g., soil classification or rock type) of each geologic unit, including the confining unit (if present);

- gross structural interpretation of each geologic unit and structural features (e.g., fractures, fault gouge, solution channels, buried streams or valleys), bioturbation zones, petrology, and discontinuities;
- development of soil zones and vertical extent and field description of soil types (prior to any necessary laboratory analysis) (see Section 3.4 for additional discussions on soil information to include in an application);
- depth of water-bearing unit(s) and vertical extent of each unit (see Section 3.5 for additional discussions on aquifer information); and
- blow counts, colors, and grain-size distribution(s).

Copies of drilling and boring logs should be submitted with the variance application.

In addition to field descriptions as described above, the applicant should provide, where necessary, a laboratory analysis of each significant soil zone (as discussed in greater detail in Section 3.4) and geologic unit. These analyses should contain the following information:

- mineralogy and mineralogic variation of confining units/layers, especially clays (e.g., microscopic analysis and other methods such as X-ray diffraction as necessary);
- petrology and petrologic variation of each unit present under a site, concentrating on those above the confining unit/layer (e.g., petrographic analysis, other laboratory methods for unconsolidated materials as deemed necessary) to determine among other things:
    - degree of crystallinity and cementation of matrix;
    - degree of sorting, size fraction, and textural variation;
    - existence of small-scale structures that may affect fluid flow;
- moisture content and moisture variation (spatial and temporal) of each significant soil zone (see Section 3.4) and geologic unit; and
- hydraulic conductivity and variation of each significant soil zone and type and geologic unit (see Sections 3.4 and 3.5 for further discussion of these parameters).

Copies of laboratory analysis results should be included with the application.

Indirect methods of geologic investigation such as geophysical studies may be used to augment the evidence gathered by direct field methods, but should not be used as a substitute for them. Surface geophysical studies, such as resistivity, electromagnetic conductivity, seismic reflection, seismic refraction, and borehole methods (e.g., electromagnetic conductivity, resistivity, and gamma ray) may yield valuable information on the depth to any confining unit, the types of unconsolidated material(s) present, the presence of fracture zones or structural discontinuities, and the depth to the potentiometric surface. Additionally, geophysical methods may have their greatest utility in correlating the continuity of formations or strata between boreholes. The result is the efficient compilation of extensive site data without drilling an excessive number of boreholes. Geophysical methods, however, should have been used primarily to supplement information obtained from direct sources.

Stratigraphic Maps. The variance applicant should use the data collected from the subsurface (borehole) investigations to prepare and submit a set of stratigraphic cross sections or maps depicting the subsurface site stratigraphy. Several cross sections may be required to depict significant geologic or structural trends and reflect geologic/structural features in relation to local and regional ground-water flow. The areal and vertical extent of the geologic units can be presented in several ways. For complex settings, the most desirable presentation is a series of structural contour maps for the top or bottom of each unit. Vertical sections and isopach maps can also be used since they are generally more graphic and are useful as supplements to the structural contour maps.

On each cross section, the applicant should identify the following: the depth, thickness, and areal extent of each stratigraphic unit; all stratigraphic zones and lenses within the near-surface zone of saturation; petrography of significant formations/strata; significant structural features; stratigraphic contacts between significant formations/strata; zones of high permeability or fracture; the location of each borehole and depth of termination; depth to the zone of saturation (as further discussed in Section 3.5); and depiction of any geophysical logs. A scale of no greater than one inch:200 feet is suggested for these maps. With an adequate number of cross section lines, a very useful and illustrative fence diagram (3-dimensional) can be constructed and submitted with the application. A table that summarizes the subsurface geologic information should also be submitted.

3.4 UNSATURATED ZONE CHARACTERIZATION

In describing the potential behavior of contaminants released to ground water from a hazardous waste tank, two major subsurface zones must be examined: the unsaturated soil zone (vadose zone), and the saturated zone or aquifer. The unsaturated zone extends from the soil surface down to the ground-water table, and collection of information on its physical and chemical properties are an important part of a subsurface investigation (and hence a variance demonstration).

Though published maps and aerial photographs of an area may provide useful soil information, detailed on-site soil explorations or surveys may be necessary to obtain detailed information. This information is typically obtained through the use of the same investigative measures discussed for obtaining geologic information, including soil borings, test pits, and geophysical investigative methods, followed by laboratory analyses of the samples collected.*/ These surveys would be especially important to conduct in heterogeneous areas that show variations in subsurface materials and stratigraphy. It is likely that at least some of the information discussed in this section for inclusion in the variance application will be acquired through the soil and rock borings conducted to investigate the subsurface stratigraphy (Section 3.3).

This section discusses the types of soil characteristics that should be investigated at a site. These characteristics include:

- soil types and extents illustrated on soil maps; and
- chemical and physical properties of the soil strata, such as organic carbon content and moisture content.

The variance applicant should submit collected data in both tabular and graphic form. As with the subsurfa[illegible] stratigraphic investigation, the applicant should submit copies of a[illegible]rilling and boring logs and laboratory analyses.

Soil Maps. In characterizing th[illegible]ial soils at homogeneous sites, published or otherwise available maps m[illegible] helpful if soils are undisturbed. While less likely to be available in adequate detail, published sources may also provide subsurface soil information. If a site has been disturbed so that published sources are inadequate, a soil survey will need to be conducted to determine the types and extents of soil at the site. The first step in a soil investigation or survey is identifying and classifying soil types at the site. The U.S. Department of Agriculture's soil classification scheme is suggested for use. This scheme is based on soil grain-size distribution.

By conducting a soil survey, the area extent of soil types at the site can be identified. Results should be presented on a plan-view soil map (suggested scale no greater than one inch:200 feet). A cross sectional analysis of the soils underlying a site should also be conducted. Results should be presented via maps showing soil thicknesses, types, and extents (lateral). The information needed to prepare these cross sections should be available from soil borings or test pits. What constitutes an adequate number of soil cross sections will vary from site to site depending on conditions, and should be determined by professional judgment. The location of each borehole or test pit should be identified on each cross sectional map.

Soil Properties. Soil properties that are important to measure or determine for understanding the fate and transport of potential contaminants include: porosity (total and effective), hydraulic conductivity, moisture content, organic carbon content, cation and anion exchange capacity, and grain-size distribution. These parameters should be determined for each significant soil zone (i.e., several soil types having similar characteristics) underlying a site and should be presented in the variance application as a table summarizing soil information. Likewise, sampling and laboratory procedures used to determine these properties should be presented and results tabulated.

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*/ See References for sources of information regarding soil investigative techniques.

Many of the soil properties discussed here will be easier to determine and measure if the assumption is made that saturated conditions (no gaseous pore space) exist. For modeling efforts, this assumption would result in a worst case scenario, i.e., a conservative approach, but often allows simpler determinations of soil parameters to be made.

All of the parameters discussed below are important in contaminant transport modeling (as discussed in Chapter 5). The soil parameters of organic carbon content, cation and anion exchange capacity, and grain size distribution will be especially important to determine and present if an applicant includes soil (or other matrix) attenuation mechanisms[9] in the calculation of exposure point concentrations (see Chapter 5).

- Total Porosity: The total porosity (the percentage of void space in the material) affects the ability of a soil to hold and possibly transmit any released contaminant. While this parameter can be estimated from the literature with knowledge of the soil type, more specific values (determined from field and/or laboratory measurements) may be required. Effective porosity is the percentage of pore space that is capable of transmitting fluid. Values for this term will likely be needed for modeling efforts and can be determined through laboratory measurements.

- Hydraulic conductivity: Hydraulic conductivity (distance/time) in the unsaturated zone is a measure of the ability of the soil to transmit fluid. It is a function of the soil moisture content and this functional relationship can be approximated from soil type. These values will be needed for modleing contaminant flow in the unsaturated zone. Hydraulic conductivity in the unsaturated zone is difficult to measure. Alternatively, the saturated hydraulic conductivity of the unsaturated zone can be used in modeling efforts. This assumption is conservative because it would imply faster contaminant movement and allows the investigator to measure saturated hydraulic conductivity by field or laboratory tests (a much simpler measurement than the estimation of the functional relationship between conductivity and moisture content in the unsaturated zone).

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[9] Attenuation mechanisms are processes that reduce the velocity or amount of a contaminant in the subsurface. Aquifer matrix or media characteristics that affect the stability of potential contaminants should also be described if they are used to support attentuation claims.

- Moisture content: During the soil survey, moisture content (dimensionless) should be measured for each soil type present at the site. This information is mainly of use for interpretive purposes, i.e., understanding the hydrogeologic setting of the site, and is measured through laboratory procedures. For modeling use, if it is assumed that saturated conditions exist, moisture contents need not be measured.

- Attentuation: To substantiate attenuation mechanisms, applicants should submit data describing the organic and mineral content, the cation and anion exchange capacity, and the grain size of each soil type along the expected path of contaminant migration. These parameters are determined through laboratory analysis and are discussed below.

  -- The degree to which many (organic) contaminants will adsorb to soil material is directly proportional to the organic carbon content (percentage) of the soil. Organic carbon contents are also important in calculating contaminant retardation in transport modeling. In making this calculation, applicants will need to measure soil values for bulk density (the ratio of the mass of soil to the bulk volume of soil). Bulk density, obviously, is dependent on the amount of sand, clay, organic matter, hydroxides, etc. in the soil.

  -- The ion exchange capacity (example of units: milliequivalents/gram) is a measure of the tendency for soil constituents, particularly clays, to attract and hold ionic contaminants. This process can be very important if there is a subsurface clay layer at a site capable of trapping potential contaminants before they reach ground water. For inorganic contaminants, this property is also important in calculating retardation (through distribution coefficients) in transport modeling.

  -- Grain-size distributions should be derived from or measured (by sieving) during soil classification. It also may be useful to further examine (through laboratory measurements) distribution of finer materials present in the soil to determine information such as amounts and type of clay. Such information can be used to further assess attenuation mechanisms such as retardation.

3.5 SATURATED ZONE CHARACTERIZATION

In addition to understanding site features such as the areal geology, it is necessary for an applicant to understand and present a thorough characterization of the ground-water system or saturated zone at a site. Unless available from prior site investigations, an extensive subsurface investigation will probably be necessary to obtain much of the information discussed in this section. This investigation will involve the drilling and implacement of ground-water wells and piezometers, and subsequent aquifer testing, laboratory analyses, and water table mapping.

The variance applicant should research available sources (reports, etc.) of information on area hydrology since this information can yield a first approximation of site-specific ground-water characteristics. These sources can also aid in the placement of investigative wells and the understanding of resulting well data. If complete enough, such sources may reduce data-gathering efforts.

The number of investigative ground-water wells that should be drilled to adequately characterize the hydrogeologic regime will vary from site to site. As small a number as three wells has been used in ground-water investigations, but a larger number is often necessary to provide accurate areal data.[10] The type of well established will depend upon aquifer characteristics (especially aquifer materials). Wells (or piezometers[11]) will need to be cased, sealed and screened as appropriate for the type of information being collected (e.g., horizontal and vertical hydraulic conductivity). Tests conducted at these wells will include sampling of geologic materials, measurements of water levels, performance of pumping tests, and analysis of water quality and quantity (or yield). Copies of all well logs and laboratory and field test results should be included with the variance application.

The level of effort spent in field and laboratory programs should be adequate to fill any knowledge gaps concerning the site's hydrogeologic setting. Discussions of the various methods and testing techniques available for the accurate definition of the ground-water regime at a site can be found in numerous references, a few of which are included in this document.

This section has been divided into two subsections:

- Subsection 3.5.1 dicusses how resulting data are used to establish aquifer characteristics including aquifer extents and composition, and hydrogeologic properties such as hydraulic conductivity and porosity.

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[10] When determining the placement of ground-water wells, the monitoring requirements discussed in Chapter 4 for establishing existing ground-water quality should be considered. This consideration would ensure that wells established to characterize ground-water flow and direction could also be used to assess ground-water quality, thus potentially reducing the necessary number of investigative wells.

[11] Piezometers are wells or boreholes that are sealed throughout most of their depth in such a way that they measure the hydraulic head at a particular depth in an aquifer.

- Subsection 3.5.2 discusses the use of collected data for establishing ground-water flow characteristics, such as rates and direction of ground-water flow.

Methods of presentation for collected data are described in the subsequent subsections.

3.5.1 Aquifer Characteristics

Using well data, detailed information should be presented in the application describing the aquifer system and the hydrogeologic properties of the saturated zone underlying the site, as discussed below. Methods used to obtain this information should also be discussed in the application.

Aquifer System. Field and descriptive efforts should characterize the uppermost aquifer as well as any lower aquifers that are hydraulically interconnected with the aquifer of interest. Listed below are several aquifer characteristics that should be identified for the aquifers of interest.

- Aquifer Boundaries: The identification of a lower boundary (or confining layer) can help delineate the vertical extent of the uppermost aquifer. Some hydrogeologic settings (e.g., alluvial depositional environments) do not contain any clear lower aquifer boundaries. In such a case, it may be adequate to limit the aquifer characterization to the expected downward migration depth of a contaminant. Professional judgment should be used in assessing interconnection between upper and lower aquifers (and the resulting levels of efforts required to characterize lower aquifers). A lack of interconnection may be indicated if the lower boundary of the upper aquifer consists of a thick confining layer (aquitard). Evidence of a significant degree of interconnection between aquifers may be indicated if the confining layer pinches out within the site boundary, the aquitard is fractured or karst, numerous wells that are inadequately sealed penetrate the aquitard, or pumping (or injection) tests show a significant response in the aquifer on the other side of the aquitard. It is also important to identify the presence and position of any hydraulic boundaries (such as impermeable barriers or beds) that limit the aquifer system at a site.

- Type of Aquifer: Following the identification of aquifer boundaries, the aquifer(s) beneath the site should be identified as being either an unconfined, or water-table aquifer (where the water table forms the upper boundary), or a confined aquifer (where the aquifer is confined between two layers of low permeability beds in a stratigraphic sequence).

- Saturated Zones: Saturated zones above the uppermost aquifer (such as low permeability clay) can also act as pathways for contaminant migration and, if present, should be identified and described. These perched water zones or perched aquifers present underneath a site should be identified.

- Stratigraphic Names: Aquifers are often called by their stratigraphic names (e.g., The Floridian aquifer in Florida). If an aquifer beneath a site is formationally named (as evidenced by common usage or published reports) such a name should be included in the application discussion.

- Classification of Units: The applicant should classify the hydrogeologic units within and below the uppermost aquifer on the basis of their lithology and hydrogeologic properties. The classification should generally extend from the surface to the aquitard underlying the uppermost aquifer. The lithology or composition of the aquifer(s) materials can be determined during investigative well drilling (including stratigraphic borings). The classification of units should be graphically presented as a hydrogeologic column or cross section with an accompanying description. This presentation can be combined with the maps discussed below for delineating the extent of the hydrogeologic units.

- Extent of Units: The applicant should delineate the areal and vertical extent of significant hydrogeologic units (the determination of the vertical extent of the uppermost aquifer has been discussed above in Aquifer Boundaries). The extents of these units can be presented in several ways. For complex settings, the most desirable presentation is a series of structural contour maps for the top or bottom of each unit. Vertical sections or columns and isopach maps are also frequently used. However, vertical sections and isopach maps may not contain all the information available. They are most useful as a supplement to the structural contour maps. Because the construction of any of these diagrams involves interpolation and extrapolation of limited data, the diagrams should also show the location of control points. For simple geologic settings in which the hydrogeologic units are laterally extensive and flat lying, maps of sections may not be necessary. For example, a table listing the elevations of the top or bottom of each unit may be adequate. These exhibits can be presented separately with a narrative discussion of the site's aquifer or aquifer system, or they may be part of the stratigraphic cross sections discussed in Section 3.3. The location of any local faults should also be indicated. Any stratigraphic units that behave as a subsurface impermeable barrier or confining layer (aquitard/aquiclude) should be identified as such.

Hydrogeologic Properties. Each of the significant stratigraphic units located in the zone of saturation should be characterized by hydrogeologic properties such as hydraulic conductivity (vertical and horizontal) and effective porosity. These parameters describe aquifer characteristics that control the movement of ground water and, hence, the ability of the aquifer to retain or pass potential contaminants. Both are needed for a general understanding of the hydrogeologic setting at a site and for ground-water transport models that use velocity measurements (as discussed in Chapter 5). Hydraulic conductivity and porosity of aquifier materials can be determined by using laboratory or field methods. Tests that are conducted to define the hydrogeologic properties of stratigraphic units should be performed in the field. Laboratory tests may be used to substantiate field test results, but should not be the sole basis for determining aquifer characteristics.

Because each of these parameters can vary from point to point even within the same aquifer, any areal variations must be identified. The amount of data needed to accurately determine hydrogeologic parameters increases with increasing heterogeneity. For example, an aquifer of extensive homogeneous beach sand will require less investigation than a glacial unit consisting of lenticular deposits of outwash sand and gravel interbedded with clayey till. Listed below are several hydrogeologic parameters that should be identified for the aquifer system.[12]

- Hydraulic Conductivity: (distance/time) refers to the ability of aquifer materials to transmit water, which in turn controls the rate at which ground water will flow under a given hydraulic gradient (discussed in Section 3.5.2). Hydraulic conductivity is controlled by the amount and interconnection of void spaces within the aquifer which may occur as a consequence of intergranular porosity, fracturing, bedding planes, etc. Ground water, and hence contaminants, have the potential to move more rapidly in an aquifer unit with a high hydraulic conductivity. Hydraulic conductivity should be determined for each aquifer system unit. In addition, hydraulic conductivities should be determined on any semipermeable or confining beds present in the subsurface, through which water may leak to or from the aquifer. Methods of determining hydraulic conductivity and considerations relative to this determination are discussed below.

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[12] More information on determining aquifer characteristics can be found in:

R. Freeze and J. Cherry, Groundwater (Prentice-Hall: Englewood Cliffs, New Jersey, 1979).

G.P. Kruseman and N.A. De Ridder, "Analysis and Evaluation of Pumping Test Data", International Institute for Land Reclamation and Improvement Bulletin 11, Wageningen, The Netherlands, 1979.

W.C. Walton, Ground-Water Resource Evaluation (McGraw-Hill: New York, 1970).

-- Hydraulic conductivity can be determined in the field using either single or multiple well tests. For units having low hydraulic conductivity, single well tests are generally used (i.e., a slug test). In evaluating the accuracy or completeness of hydraulic conductivity data, the applicant should be aware that: (1) hydraulic conductivity determinations based upon multiple well tests are preferred; (2) multiple well tests provide more complete information because they characterize a greater portion of the subsurface; and (3) the use of single well tests will require that more individual tests be conducted at different locations to adequately define hydraulic conductivity variation across the site.

-- Single well tests, more commonly referred to as slug tests, are performed by suddenly adding or removing a slug (known volume) of water from a well and observing the recovery of the water surface to its original level. Similar results can be achieved by pressurizing the well casing, depressing the water level, and suddenly releasing the pressure to simulate removal of water from the well. The vertical extent of well screening will control the part of the geologic formation that is being tested. The part of the column above or below the screened interval that has not been tested may also need to be tested for hydraulic conductivity. Enough tests should be run to provide representative measurement of hydraulic conductivity and to document lateral variations of hydraulic conductivity at various depths in the subsurface.[13]

-- For hydraulic units having high hydraulic conductivity, multi-well pumping tests are preferred. Multiple well tests, more commonly referred to as pumping tests, are performed by pumping water from one well and observing the resulting drawdown in nearby wells. Tests conducted with wells screened in the same water-bearing formation provide hydraulic conductivity data. Tests conducted with wells screened in different water-bearing zones furnish information concerning hydraulic communication. Multiple well tests for hydraulic conductivity are advantageous because they characterize a greater proportion of the subsurface and, thus, provide a greater amount of detail than single well tests.

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[13] Hydraulic conductivity information generally provides average values for the entire area across a well screen. For more depth discrete information, well screens would have to be shorter. If the average hydraulic conductivity for a formation is required (for transport modeling), entire formations may have to be screened, or data taken from overlapping well clusters.

-- Laboratory methods can be used to estimate hydraulic conductivity; e.g., hydraulic conductivity may be determined on a core sample of the aquifer by using either a constant-head or a falling-head permeameter. However, field methods provide the best definition of the hydraulic conductivity in most cases.

-- Heterogeneity in aquifer materials will cause variations in hydraulic conductivity that should be evaluated and quantified. Additionally, hydraulic conductivity may show variations with the direction of measurement. This variation is termed anisotropy, and, if present, the degree of it should be evaluated.

-- It is important that measurements define hydraulic conductivity both vertically and horizontally across the site. In assessing the completeness of hydraulic conductivity measurements, the applicant should also consider results from the boring program used to characterize the site geology. Zones of high permeability or fractures identified from drilling logs should be considered in the determination of hydraulic conductivity. Additionally, information from boring logs can be used to refine the data generated by single well or pumping tests.

- Permeability: In the saturated zone, the permeability (distance/time) of aquifer materials is directly related to the hydraulic conductivity, and also describes the ability of a medium to transmit fluid. Whereas the conductivity is a function of the media and the fluid moving through it, permeability is a function of the media alone (a function of pore size). Knowing one of these parameters can lead to the determination of the other. While the presentation and accurate measurement of hydraulic conductivity data has been suggested herein for inclusion in the variance application, it may be useful to present permeability values also. Permeability data may also play a role in the transport modeling efforts of Chapter 5, and can be determined in the field or laboratory.

- Effective Porosity: If there are dead-end pores within the ground-water system or ground water is for some reason immobile, then the entire pore space (the total porosity) is not effective in transmitting fluid and a correction to the porosity must be made. This adjusted value of porosity is called the effective porosity (dimensionless). Effective porosity, therefore, refers to the amount of interconnected pore space available for transmitting water. In the laboratory, effective porosity can be determined as the ratio of the volume of water yielded by gravity flow to the volume of soil or rock material. It may be adequate to estimate this parameter by analogy with other field results. Effective porosities should be determined for each aquifer system unit.

Depending on the ground-water transport model that is chosen for use in estimating exposure point concentrations (as discussed in Chapter 5), the following parameters may also need to be measured or estimated:

- Specific Yield/Storage: For unconfined aquifers, specific yield expresses the volume of water that will drain freely from an aquifer per unit area. For confined aquifers, specific storage is the volume of water released from, or taken into, storage in the aquifer per unit area. Field pump test methods are usually performed to estimate these parameters. Storativity values or storage coefficients can be calculated from these parameters.

- Transmissivity: This parameter expresses the flow of ground water over time through a specified areal section of an aquifer. It can be estimated by multiplying the hydraulic conductivity by the aquifer depth, or by the analysis of field pump tests.

- Attenuation Properties: If a ground-water transport model is chosen that evaluates and computes mobility (e.g., retardation) or persistence (e.g., degradation), attenuative properties of the aquifer materials should be investigated. This investigation could include the measurement of factors discussed above with respect to soil attentuation, such as the organic carbon content of units of the saturated zone. Values obtained or estimated for such attenuation mechanisms should be presented in the application along with a discussion of how they were obtained and used.

- Dispersivity: The dispersivity or spreading of a flowing substance due to the nature of the porous medium of the aquifer materials may also need to be evaluated for some transport models. The greater the dispersion, the greater the dilution of a migrating contaminant. While many models make general estimates of this process, some may require more site-specific estimates of this parameter. Dispersion would usually be estimated by analogy, but can be determined from field tests.

For each of the parameters discussed in this section and presented for inclusion in the variance application, the methods used to obtain the data should be thoroughly discussed. A summary of the hydrogeologic properties of each stratigraphic zone within the zone of saturation should be submitted by the applicant. This summary should include a table that provides the aquifer name, stratigraphic zone, and lithologic composition and values for hydraulic properties measured (this section has stressed the measurement of hydraulic conductivity and effective porosity). Additionally, these properties should be discussed in regards to the ground-water regime as a whole.

3.5.2 Ground-Water Flow Characteristics

The revised hazardous waste tank regulations state that the Regional Administrator will consider in a variance application the potential adverse effects of a contaminant release on ground-water and surface water quality, taking into account the quantity and quality of ground water and the direction of ground-water flow.[14] The amount of ground water at a site and the direction in which it flows are important factors to consider because they are essential components of an analysis of the fate and transport of potential contaminants in the ground water.

This section describes the determination and assessment of the site characteristics with respect to recharge and discharge zones, ground-water flow directions, ground-water flow rates, and other considerations associated with these factors. In addition to the inclusion of maps and tables of measurements as discussed in this section, the applicant should present a thorough narrative discussion of investigative results identifying: (1) all dominant ground-water flow directions, including both horizontal and vertical components in upper and (significant) lower aquifers; (2) relationships of flow to discharge or recharge areas; and (3) any temporal variations in ground-water levels. As with other data identified in this chapter for collection and presentation, ground-water flow characteristics are important both in the understanding of a site's hydrogeologic setting and in the determination of exposure point concentrations (see Chapter 5).

Recharge/Discharge Zones. To aid in the understanding of the ground-water flow regime, and to aid in the identification of potential paths for contaminant migration, the location of any proximate recharge or discharge zones should be identified in the application. This identification is determined in part by a site's location in the watershed. The applicant probably does not need to quantify this information; rather, a general indication of discharge or recharge characteristics could be presented.

For unconfined aquifers, recharge areas are usually topographic highs, while discharge areas are topographic lows. Discharge/recharge areas also indicate relative water table depth. In discharge areas, the water table is found close to or at the land surface, while at recharge areas, there is often a deep unsaturated zone between the water table and the land surface. A water-table contour map can be used to locate these areas.

Recharge and discharge in confined aquifers is more complex. Discharge and recharge may occur where the aquifer outcrops. Some discharge may also occur in the form of upward leakage in areas of upward hydraulic gradient. Recharge can also occur by downward flow through the confining layer.

Ground-Water Flow Directions. The hydrogeologic field investigations should include a program for precise monitoring of the ground-water levels, including areal and temporal variations. This program will involve the measurement of water levels in the observation wells installed for the purpose of investigating the saturated zone (as discussed in Section 3.5.1). Water level data also are used to establish the depth to ground water at a site, as well as in establishing hydraulic gradients and flow directions.

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[14] Section 264.193(g)(2)(ii)(A) and (iii)(A) (51 Federal Register 25475, July 14, 1986).

Some considerations in the establishment and measurement of observation wells (piezometers) include:

- If the aquifer beneath a site is confined (i.e., upper boundary is of low permeability) and/or there are significant lower aquifers, the elevation of water levels (or potentiometeric surfaces) in wells screened to monitor such units should be measured. These measurements require a larger number of wells (of varying depths) than those necessary to examine a single, shallow, unconfined aquifer.

- Water levels in piezometers should be allowed to stabilize for a minimum of 24 hours after well construction and development prior to measurement. In low yield situations, a longer recovery interval may be required.

- Generally, water level measurements from boreholes, piezometers, or monitoring wells used to examine the same unit should have been collected within a 24-hour period. This practice is adequate if the magnitude of change is small over that period of time. There are other situations, however, such as tidally influenced aquifers or aquifers being actively recharged due to a precipitation event, which necessitate that all measurements be taken within a short time interval.

Parameters necessary to measure or ascertain in the determination of ground-water flow directions include:

- Depth to Ground-water: Water level data should be submitted with the application for each piezometer or well. Data can be presented in tabular form and should include well locations and identification, well depth, screened interval, ground-water elevation, and sampling date. Once established, the depth to the water table (for unconfined aquifers) or ground-water depth should be graphically shown for the site location. This demonstration can be done by indicating the water table or ground-water level on the stratigraphic maps used to illustrate the relationship of subsurface materials to ground water (as discussed in Section 3.3). Measurements can be represented as the average depth to ground water at a well point. If significant variations in levels occur due to temporal factors (such as seasonal variations), it will be important to present level measurements over time.

- Potentiometric Surface: Using water level (hydraulic head) distributions at the site, water level contour maps should be prepared. These contour maps should indicate the tank(s) location, ground-water elevations, and isopaths connecting elevations. Vectors indicating the direction of flow should be added to these maps (from high head to low head).[15] For sites with unconfined aquifers and no underlying significant (interconnected) hydraulic units, just one map, the water table contour map, needs to be prepared. For sites with more than one aquifer unit, contour maps of potentiometric surfaces (as determined from piezometer measurements) for each lower unit of interest need to be prepared. The degree of heterogeneity in aquifer units will affect water levels or potentiometric surfaces.

- Hydraulic Gradients: Using the potentiometric surface contour maps discussed above, hydraulic gradients (the change in elevation of the water table over distance) can be established. This determination will represent the hydraulic gradient in the horizontal direction. Hydraulic gradients should also be determined for any significant lower units or confined aquifers.

- Vertical Components of Flow: In addition to considering the components of flow in the horizontal direction, the applicant must assess the vertical components of ground-water flow. This assessment may require the installation of piezometers in clusters. A piezometer cluster, or nest, is a closely spaced group of wells screened at different depths to measure vertical variations in hydraulic head. Placement of vertically nested piezometers in closely spaced separate boreholes is the preferred method, since information obtained from multiple piezometer placement in single boreholes may generate erroneous data.[16] Collected piezometric data should be submitted with the application in tabular form for each well nest, including well locations and identification, well depth, screened interval, ground-water elevation, and sampling date. Determinations of vertical flow gradients should be made from the piezometric measurements, which can aid in determining discharge and recharge zones, and aquitard characteristics. The measurements of hydraulic heads from these nested piezometers can be used to construct flow nets (a vertical cross section of the site illustrating a pattern (or flowlines) of hydraulic heads). The use of flow nets can aid in the determination of vertical flow gradients. All calculations and assumptions should be described in detail.

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[15] The applicant should be aware that the determination of horizontal flow directions may be inaccurate if water level countour maps are constructed using wells or piezometers at different depths.

[16] Piezometer measurements should be determined along a minimum of two vertical profiles across the site. These profiles should be cross sections roughly parallel to the direction of ground-water flow indicated by the potentiometric surface maps.

Ground-water Flow Rates. The applicant must provide in the variance application an assessment of ground-water flow rates or velocities beneath a site. Along with flow direction, this assessment is one of the most important pieces of hydrogeologic information supplied in the variance demonstration. Methods for determining flow rates are discussed below.

- Field Determination of Flow Rates: Field techniques for the measurement of the rate of ground-water flow, such as tracer tests, are difficult to perform and will probably not be necessary to conduct. Rather, information obtained from analysis of the hydrogeological properties and flow directions (hydraulic gradients) will allow the calculation of ground-water flow velocity by a simple modification of Darcy's law as discussed below.

- Calculations of Flow Rates: Darcy's law is based on empirical evidence that the flux water through an aquifer is proportional to the hydraulic gradient. The constant of proportionality is the hydraulic conductivity. The flux of ground water flowing through an aquifer can be calculated using the following equation:

$$V = -K \cdot i$$

where

V = the flux (or quantity) of water flowing through a cross-sectional area (distance/time)

K = hydraulic conductivity (distance/time)

i = hydraulic gradient (distance/distance) or loss of head per unit length of flow

Ground-water flux values can be used to determine quantities of ground-water discharge, and can also be used to obtain velocity values for the rate of ground water moving through the pore spaces of the aquifer:

$$V' = \frac{V}{n_e}$$

where

V' = average linear pore water velocity of ground water (distance/time)

n_e = effective porosity of the aquifer (dimensionless)

All calculations and assumptions used in the determination of flow rates should be included in the application.

Other Considerations for Assessing Ground-Water Flow Characteristics. Factors such as hydrologic fluctuations (e.g., seasonal variations, well pumping, and tidal processes), low or high gradients, and aquifer heterogeneity and anisotropy can result in variations in ground-water levels and flow patterns, and can make the accurate determination of ground-water flow difficult. Consideration of these factors is more important at sites with low hydraulic gradients. A program undertaken to investigate ground-water flow patterns at a site should identify and assess any processes that contribute to or affect ground-water patterns below the site. If these processes are not evaluated, the uncertainty introduced by neglecting them should be estimated. Several of these considerations are discussed below:

- Seasonal Variations: Seasonal variations in ground-water use and recharge can cause significant changes in ground-water flow directions. In extreme situations, a flow reversal can occur. For sites where this phenomenon may be important, water table or piezometric surface maps should be submitted that represent yearly averages and the two seasonal extremes. In addition, the applicant should provide information describing the temporal changes in ground-water flow direction using records compiled over a period of no less than one year. Seasonal variations in flow direction are more likely to occur in unconfined systems.

- Pumping: Off-site or on-site well pumping may affect the direction of ground-water flow. Municipal, industrial, or agricultural ground-water use may significantly change ground-water flow patterns and levels over time. Pumpage may be seasonal or dependent upon water use patterns. Water level measurements in piezometers must have been frequent enough to detect such water use patterns. For sites where such variations occur, the rate of ground-water withdrawal in the vicinity of the facility should be summarized in tabular form and include well location, depth, type of user, and withdrawal rates. The zone of impact created by any major well or well field withdrawal should be identified on a good site map. The map should include modeling of drawdown curves.

- Tidal Processes: Natural processes such as riverine, estuarine, or marine tidal movement may result in variations of well water levels. An applicant should document the effects of such patterns.

- Gradient Considerations: In areas of low or flat horizontal gradients, small errors in water level measurements or small transient changes in water levels can make determination of flow direction and rates unreliable. Determination of flow patterns is also difficult where high or steep vertical gradients exist (often in surficial units). Often, a near-surface, shallow water table aquifer may overlie an aquifer of higher permeability, resulting in vertical head gradients.

- Aquifer Heterogeneity: The degree of heterogeneity in aquifers may range from fairly moderate to extreme. Because the potentiometric surfaces, or water levels, in heterogeneous aquifers are not smooth, regular surfaces, determination of ground-water flow patterns is difficult. At the contact between two geologic materials, the hydraulic gradient will be discontinuous. For some aquifers, such as fractured rock and karst aquifers, the heterogeneity is much more complex.

- Anisotropy: Anisotropy is the dependence of a property on direction. Many aquifers display a horizontal-vertical anisotropy. Aquifers that may demonstrate anisotropy include aquifers in fluvial sandstone, fractured rocks, or steeply inclined strata. Ground-water flow direction and rates are difficult to determine from water level data in these types of anisotropic aquifers. The dependency of hydraulic conductivity on the degree of anisotropy has been discussed previously.

The hydrologic fluctuations and other factors discussed above that make the determination of flow patterns unreliable can often be overcome by an expanded effort in water level monitoring. For seasonal variations in water levels, a higher frequency monitoring schedule is necessary. For low horizontal gradients, the effects of short-term changes in water levels can be analyzed by installation of continuous recorders in selected wells. In aquifers having significant vertical gradients, piezometers completed at various depths may be required in order to provide a three-dimensional description of the flow field. For heterogeneous and anisotropic aquifers, more water level monitoring wells and more field tests for hydraulic properties are required.

3.6 SURFACE WATER CONSIDERATIONS

An important part of assessing exposure to releases is the identification of surface water bodies that have the potential to be contaminated by a release from the applicant's tank system(s). This identification is also an important feature of the revised hazardous waste tank regulations, in that the Regional Administrator will consider the proximity and withdrawal rates of ground-water users (as discussed in Chapter 4) and the proximity of the tank system to surface waters (discussed here), in evaluating a secondary containment variance demonstration.[17]

Proximity to Surface Water. At a minimum, all surface waters within approximately five kilometers downgradient or downstream of the facility should be considered when preparing a variance application. Professional judgment, however, should be exercised in determining if surface waters beyond this distance should be included. For example, if the ground-water velocity is high in the vicinity of the facility, surface water well beyond five kilometers may need to be considered. Also, if a reservoir used for drinking water is beyond five kilometers away, but is fed by a stream or river that flows near the facility, it should be included in the variance application.

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[17] Sec. 264.193(g)(2)(ii)(B) and III(c) (51 Federal Register 25475, July 14, 1986).

To summarize proximate surface water, the applicant should provide a map of the facility and the surrounding area. The map should be appropriately scaled and include contour lines to show the topography of the land. On this map the facility and all surface water bodies within five kilometers downstream or downgradient should be identified, including the following water bodies:

- streams;
- rivers;
- lakes;
- ponds;
- estuaries;
- marine waters; and
- wetlands (e.g., marshes, swamps, bogs, etc.).

All potential runoff or drainage pathways (e.g., ditches, sewers) from the facility to surface waters should also be marked and identified on the map. This information can often be obtained from U.S.G.S. topographic maps. As discussed in Section 3.3.2, the topographic map prepared for inclusion in the variance application can also be used to depict this information. In addition to this map, the applicant should create a table that lists each surface water body, the corresponding shortest distance from the facility to the surface water body, and available information on the potential means of contamination (i.e., ground-water discharge and/or surface runoff fed by previously contaminated water). The surface water bodies should be listed in order from shortest to longest distance from the tank.

Surface Water Characteristics. In addition to identifying the physical proximity of surface water bodies to the facility and estimating the travel time of releases (discussed in Chapter 5, Exposure Point Concentrations), the physical characteristics of surface water bodies may need to be investigated if the applicant is to further consider dilution and transport within surface waters (i.e., use surface water dilution to demonstrate no substantial hazard).

This investigation will be important for applicants whose tank system(s) could, in the case of a leak, provide direct releases to surface water, and can also be important for sites where the ground water directly feeds surface water bodies. Once obtained, these parameters can be used to estimate hazardous constituent transport within surface waters and the dilution potential and mixing mechanisms of each type of surface water. This information will likely be used in the estimation of exposure point concentrations (as disccused in Chapter 5) and possibly in preparing an environmental impact evaluation (see Chapter 7).

For all surface waters that potentially could be contaminated by a release, the applicant should provide a description of appropriate physical characteristics, such as:

- surface area;
- mean depth;
- volume or cross-sectional area;
- turbidity;
- reaeration rate;
- temperature patterns; and
- hydraulic residence time or flow rate.

In addition, for estuarine and marine waters, tidal periodicity and amplitude should be identified. For streams and rivers, flow rate information should include: (1) average flow; (2) lowest flow that would be expected to occur during a continuous 7-day period, once every 10 years; and (3) lowest recorded flow rate. These parameters are less difficult to obtain than many of the previously discussed hydrogeologic parameters and are not discussed in detail here.[18]

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[18] Numerous references are available on methods characterizing surface waters including:

Ven Te Chow, Open-Channel Hydraulics (McGraw-Hill: New York, 1959).

Ven Te Chow, ed., Handbook of Applied Hydrology (McGraw-Hill: New York, 1964).

CHAPTER 4

SURROUNDING LAND USE, WATER USE, AND WATER QUALITY CHARACTERISTICS

This chapter presents guidance on identifying and obtaining relevant information on surrounding land use, water use, and water quality characteristics. Specifically, this chapter presents guidance on obtaining and presenting the information necessary to comply with Sections 264.193(g)(2)(ii),(iii), and (iv) of the RCRA hazardous waste tank regulations (51 Federal Register 25475, July 14, 1986). These sections require the applicant to consider the potential adverse effects of a release on ground-water quality, surface water quality and surrounding land. The applicant must take into account the following factors:

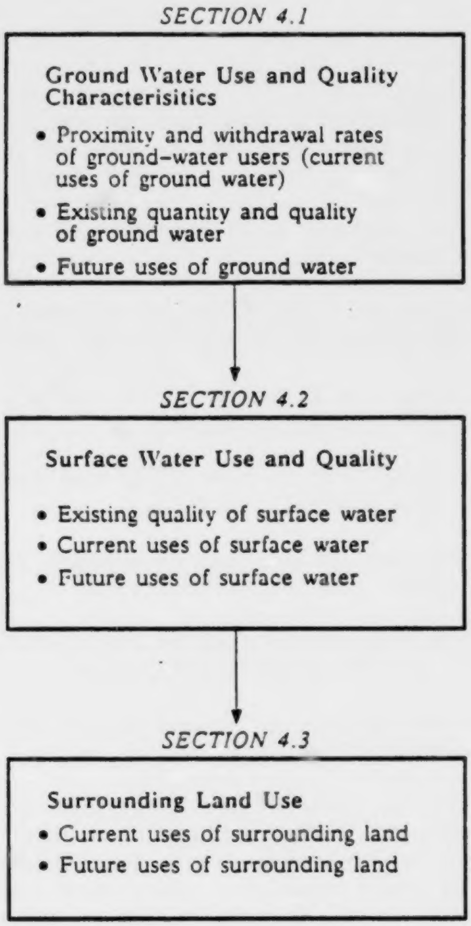
- quantity and quality of ground water (Sec. 264.193(g)(2)(ii)(A)and Sec. 264.193(g)(2)(iii)(E));
- proximity and withdrawal rates of ground-water users (Sec. 264.193(g)(2)(ii)(B));
- current and future uses of ground water in the area (Sec. 264.193(g)(2)(ii)(C));
- current and future uses of surface waters in the area (Sec. 264.193(g)(2)(iii)(D));
- current and future uses of the surrounding land (Sec. 264.193(g)(2)(iv)(B)); and
- existing quality of ground water (Sec. 264.193(g)(2)(ii)(D)).

These factors can be grouped into three general categories: ground-water use and quality characteristics, surface water use and quality characteristics, and surrounding land use characteristics. Accordingly, this chapter is organized into three basic sections. Section 4.1 discusses ground-water use and quality characteristics, Section 4.2 discusses surface water use and quality characteristics, and Section 4.3 discusses surrounding land use. Within each section, the type of information that the applicant will be required to obtain is presented first, followed by a brief discussion of potential information sources, suggestions for presenting the information, and how the information will be used in the risk assessment process.

Exhibit 4-1 provides a general overview of the information gathering steps described in this chapter. This chapter presents separate discussions of the information needed to characterize ground-water and surface water use and quality and surrounding land use; however, use of ground water, surface water, and surrounding land are interrelated (e.g., use of ground water for irrigation is likely to occur in arid agricultural areas where surface water sources are not readily available). In addition, uses of surface water and ground water depend in part on water quality (e.g., ground water in the area

Exhibit 4-1

OVERVIEW OF PROCESS TO CHARACTERIZE SURROUNDING LAND USE, WATER USE, AND WATER QUALITY


SECTION 4.1
Ground Water Use and Quality Characterisitics
• Proximity and withdrawal rates of ground-water users (current uses of ground water)
• Existing quantity and quality of ground water
• Future uses of ground water
SECTION 4.2
Surface Water Use and Quality
• Existing quality of surface water
• Current uses of surface water
• Future uses of surface water
SECTION 4.3
Surrounding Land Use
• Current uses of surrounding land
• Future uses of surrounding land

may not be of sufficient quality to be used for drinking purposes). Therefore, although this chapter provides a sequential discussion of ground-water quality and use, surface water quality and use, and surrounding land use, in practice it will probably be necessary for the applicant to obtain some information in all three of these areas before completing an evaluation of any one particular area.

Not all of the water quality, water use, and land use parameters discussed in this chapter will need to be characterized at all sites. The applicant should exercise professional judgment, given the general guidelines presented in this chapter, in determining precisely which water use and water quality parameters are relevant for the facility, and in determining the level of detail necessary to adequately support the risk-based variance application. Those qualified to exercise professional judgment, as the term is used in this chapter, may include hydrologists, geohydrologists, environmental engineers, sanitary engineers, and civil engineers.

4.1 GROUND-WATER USE AND QUALITY CHARACTERISTICS

Existing quality of ground water and current and future uses of ground water must be considered by the applicant in evaluating the present and potential hazard to human health and the environment posed by a release of contaminants from a tank system. Characterizing existing quality of ground water is an important task for two reasons. First, existing ground-water quality normally defines the baseline conditions for evaluating risks to human health and the environment. Second, existing ground-water quality in part determines current uses and affects future uses. In addition, determining ground-water uses is an important initial step in identifying potential exposure pathways.

This section is organized into four subsections. Section 4.1.1 discusses the information needed to characterize the proximity and withdrawal rates of current users. Section 4.1.2 provides guidance for determining the existing quantity of ground water in the area. Section 4.1.3 provides guidance for assessing the existing quality of ground water, and Section 4.1.4 provides guidance for identifying future uses of ground water.

4.1.1 Proximity and Withdrawal Rates of Ground-Water Users

The proximity and withdrawal rates of ground-water users are important factors in determining the potential adverse effects of a release on human health and the environment. The proximity of ground-water users will affect both the time it takes a contaminant to reach the user and the concentration of contaminants in the user's ground water. The withdrawal rate (i.e., the daily or annual volume of water pumped from an aquifer) is used to assess the total amount of contaminants the user is exposed to and, in some cases, any influence the rate has on the direction and magnitude of ground-water flow in an area.

For each ground-water user identified in the surrounding area, the following information should be provided:

- well location and distance from potential release source (i.e., tank system);
- well depth;
- type of user:
    - potable (municipal and residential),
    - domestic non-potable (e.g., lawn watering),
    - industrial,
    - agricultural,
    - artificial recharge[1]; and
- withdrawal rates (peak, annual, and seasonal).[2]

The above information can be presented using a map and an accompanying summary sheet. Worksheet 4-1 can be used as a summary sheet.

Possible sources for information relating to proximity and withdrawal rates of ground-water users include local and regional water districts or companies, state agencies, federal agencies (EPA, U.S. Geological Survey, U.S. Department of Agriculture) and various state, federal, and private organization data bases. A detailed list of these information sources is contained in Appendix B of this document.

4.1.2 Existing Quantity of Ground Water

The existing quantity of ground water is an important factor in evaluating any potential risks to human health or the environment that could result from a tank release. The existing quantity of ground water may affect the degree of dilution of a release into ground water and subsequent migration of the contaminant plume. In addition, the quantity of ground water affects the potential yield of the aquifer and any potential future uses of the ground water in the area for domestic, industrial, or agricultural purposes.

It is difficult to determine precisely a single value for the quantity of ground water in the area. The quantity of water stored in an aquifer may vary from season to season and from year to year. Aquifers are generally moving reservoirs of water rather than static water resources and, therefore, the total quantity of ground water stored or traveling through the facility

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[1] Although artificial recharge wells (i.e., wells used to inject water into an aquifer) do not actually constitute a "use" of ground water, they do affect the geohydrological characteristics of an aquifer (i.e., magnitude and direction of flow) and could affect the environmental transport of contaminants.

[2] Seasonal withdrawal rates would apply to uses of ground water that vary significantly throughout the calendar year. For example, agricultural use would generally be confined to the growing season. In such cases, a range of withdrawal rates and the average withdrawal rate for in season and out of season use should be provided.

WORKSHEET 4-1

PROXIMITY AND WITHDRAWAL RATES OF GROUND-WATER USERS

INSTRUCTIONS:

1. Indicate the location of ground-water wells in the area.
2. List the approximate distance of the well in meters from the release source (i.e., tank system).
3. Indicate the depth of the well in meters.
4. Indicate the type of user associated with each well (e.g., domestic, residential, agricultural).
5. Specify peak, annual, and seasonal (if applicable) withdrawal rates.
6. Add any additional comments, such as the nature of seasonal use.

Facility ID: ____________
Date: ____________
Analyst: ____________
Quality Control: ____________

Well ID #	Location	Distance from Release Source (m)	Well Depth (m)	Type of User	Withdrawal Rates (g/day) Peak	Annual	Seasonal	Comments
22	Smith Residence	1 km	10 m	Domestic	400	250		
14	Browns Farm	2 km	12 m	Livestock watering	1,400	800		
12	Browns Farm	1.5 km	14 m	Irrigation			250	From May until August

vicinity is time dependent. To assess ground-water quantity, the aquifer yield should be characterized and discussed. Most of the hydrogeological data necessary for characterizing aquifer yield will already have been collected as part of the hydrological characterization performed as discussed in Chapter 3.

Yield is an important factor for evaluating the development and utilization of ground-water resources. Generally, the development and utilization of ground-water resources is controlled such that the annual volume of water withdrawn from an aquifer does not exceed annual replenishment to the aquifer (otherwise the aquifer's water supply would be depleted). The yield provides an indication of the quantity of water than can be withdrawn annually and the total quantity of water stored in the aquifer. To characterize the yield of the aquifer underlying the facility, the following estimates of yield should be provided.[3]

- **Safe yield**: the quantity of water that can be withdrawn annually without the ultimate depletion of the aquifer.
- **Maximum sustained yield**: maximum rate at which water can be withdrawn on a continuing basis from a given source.
- **Permissive sustained yield**: maximum rate at which withdrawals can be made legally and economically on a continuing basis for beneficial use without the development of undesired results.[4]
- **Maximum mining yield**: total storage volume in a given source which can be withdrawn and used.
- **Permissive mining yield**: maximum volume of water which can be withdrawn legally and economically, to be used for beneficial purposes, without causing an undesired result.[4]

These estimates will be useful in assessing the productive capacity of the aquifer for future ground-water uses. The applicant should first contact state planning agencies for these estimates. Planning agencies will likely have these estimates for use in ground-water resource planning. If these estimates are not available they will need to be calculated from some of the hydrogeologic data collected for Chapter 3. While some of these calculations are relatively straightforward,[5] a qualified professional will be needed to derive the more complex estimates.

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[3] Source of definitions: John W. Clark, Warren Viessman, Jr. and Mark J. Hammer, Water Supply and Pollution Control, 3rd ed. (New York: Harper & Row, Publishers, 1977), p. 75.

[4] Examples of undesired results include: increased energy costs by lowered water levels; impairment of water quality; and infringement of rights of other users.

4.1.3 Existing Quality of Ground Water

The existing quality of ground water affects current and potential uses of ground water and also provides a baseline for evaluating the incremental potential human health and environmental risks due to a release of contaminants from the tank system. The quality of ground water can be affected by both naturally occurring sources, such as leaching of minerals from the aquifer medium, and human sources, such as leaking of petroleum or chemical products from underground storage tanks or the downward migration of pesticides and fertilizers from agricultural areas. The primary purpose of this subsection is to characterize the existing background quality of ground water in the area (i.e., the quality of the ground water prior to a release of contaminants).

In evaluating the background water quality in the area, the applicant must consider not only possible background concentrations of the selected indicator chemicals, but also the background concentrations of other RCRA Appendix VIII[6] hazardous constituents. Existing contamination associated with indicator chemicals or other RCRA Appendix VIII hazardous constituents may be due to natural conditions in the area, prior releases from the hazardous waste tank system, or prior releases from other sources in the surrounding area. Assessing background concentrations of RCRA Appendix VIII hazardous constituents is necessary to establish an existing baseline of environmental contamination to which the incremental effects of a future hazardous waste tank release can be added. For example, existing levels of contamination in an area may be below a level at which significant risks to human health or the environment would be expected to occur. Adding the contamination expected to result from a tank release could, however, result in overall levels of contamination above the significant risk threshold or above applicable environmental standards, even if the tank release is not sufficient by itself to pose a significant risk.

Measuring the ambient concentrations of every RCRA Appendix VIII hazardous constituent is not generally feasible. To adequately assess background ground-water quality, the applicant should attempt to identify other potential release sources in the area (e.g., CERCLA sites, RCRA facilities, municipal landfills, agricultural areas, or surface water dischargers) and identify which RCRA Appendix VIII constituents are most likely to have been released by each source. Some of the chemicals on the list of background chemicals may also be indicator chemicals, particularly if the facility has experienced a prior tank system release. When determining which chemicals to include on a list of background chemicals, the applicant need not include all the selected indicator chemicals; only those indicator chemicals that are likely to be currently present in surrounding ground-water (i.e., if there is a suspected human or natural release source) should be included on the background chemical list.

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[5] For example, for an unconfined aquifer the maximum mining yield is the product of the specific yield, the water table height, and the aquifer area. For a confined aquifer the maximum mining yield is the product of the specific storage, the hydraulic head, and the aquifer area.

[6] 40 CFR Part 261, Appendix VIII.

For each chemical on the list of background chemicals, the applicant should provide information on the concentration of the chemical in surrounding ground water. As part of a RCRA Subpart F ground-water monitoring program (40 CFR 264.97-264.100), some facilities may already have obtained data on concentrations of hazardous constituents in surrounding ground water. These historical monitoring data, if available, may be sufficient for assessing background ground-water quality, provided that the data are recent, are derived using EPA-approved analytical procedures, and are from sampling points relevant to a potential tank system release. It is important to note that the term "background concentration," as used in this document, has a different meaning than when used in the RCRA detection and compliance monitoring regulatory context. For the purpose of the risk-based variance, background concentration means existing ambient concentrations of chemicals in all directions surrounding the facility and does not refer primarily to upgradient concentrations of background chemicals. Consequently, historical monitoring data for all wells, both upgradient and downgradient of the tank system, should be submitted. If available, data for at least the previous two years of monitoring should be submitted.

In cases where sufficient appropriate historical monitoring data are unavailable, the applicant may need to install a ground-water monitoring system or add to an existing system in order to adequately assess background ground-water quality. Sampling of neighboring residential wells may also provide useful data. Guidance on siting, constructing, and sampling monitoring wells is provided in the RCRA Ground-Water Monitoring Technical Enforcement Guidance Document (TEGD).[7] Under RCRA Subpart F regulations for solid waste management units (40 CFR 264.97), background concentrations are usually determined based upon a full year of quarterly sampling of monitoring wells. Given the 180 day time limit for completing the variance application, however, it will not be feasible for applicants lacking historical monitoring data to conduct a full year of sampling. Therefore, background water quality should be determined based upon at least two separate samplings of existing or newly installed monitoring wells and neighboring residential wells, if feasible given the variance application time constraints and the time required to analyze samples and interpret sampling results.

For facilities that have experienced a prior tank system release, the applicant should also submit the results of any sampling or monitoring, or hydrogeological investigations conducted in connection with the release (if available) and should provide references to any reports submitted to the Regional Administrator in connection with the release and in accordance with the requirements of 40 CFR 264.196 (51 Federal Register 25477, July 14, 1986). Information on prior releases is important for two reasons. First, prior releases contribute to the baseline level of environmental contamination to which the effects of future releases will be added. Second, data on the environmental fate and transport of hazardous constituents from prior releases could prove very useful in predicting the migration of hazardous constituents from future releases. In particular, historical data or hydrogeological investigations documenting the magnitude and rate of migration of the contaminant plume could be very useful in assessing the migration pattern and risks of a future release.

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[7] EPA, RCRA Ground-water Monitoring Technical Enforcement Document (TEGD), Office of Solid Waste and Emergency Response, September 1986.

Worksheet 4-2 provides instructions and a format for presenting the necessary information on background ground-water quality. The applicant should provide information on the range and median of measured background concentrations for each RCRA Appendix VIII constituent on the list of background chemicals, distinguishing between upgradient data and downgradient data. In addition to completing Worksheet 4-2, the applicant should also submit supporting documentation of results including sampling logs, laboratory analytical reports (including Quality Assurance/Quality Control documentation), and chain of custody procedures.

4.1.4 Future Uses of Ground Water

Although the ground water in the vicinity of the facility may not currently be in use, the potential may exist for this ground water to be used in the future. Future uses of ground water will be considered in evaluating risks to human health and the environment (Chapter 5). For example, contamination of an unused aquifer would generally not pose an imminent risk to human health. If a local water utility is planning to utilize the aquifer as a drinking water source in the future, however, then contamination of the aquifer may pose a future risk to human health. In such a case, the nature and magnitude of that risk would need to be discussed by the applicant in the variance application. Several factors may influence the potential future use of an aquifer or a portion of an aquifer. These factors include:

- quality of ground water;
- treatability of ground water (if appropriate);
- potential yield of ground water;
- zoning or land use restrictions;
- ground-water use restrictions; and
- demographic factors (e.g., population growth).

Each of these factors is discussed briefly below.

The **quality of ground water** is an important determinant of potential use. EPA has already developed some draft guidelines for evaluating potential use of ground water based on ground-water quality. In general, water with a total dissolved solids (TDS) concentration greater than 10,000 mg/l is unsuitable for drinking purposes.[a] Contamination of ground water caused by either natural processes or human activity may preclude the use of the ground

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[a] EPA, Guidelines for Ground-Water Classification under the EPA Ground-Water Protection Strategy, Final Draft, Office of Ground-Water Protection, December 1986, p. 39.

WORKSHEET 4-2

MEASURED GROUND-WATER CONCENTRATIONS OF BACKGROUND CHEMICALS

INSTRUCTIONS :

1. List all selected background chemicals chemicals.
2. For each chemical listed, identify the release source.
3. List the range of measured upgradient ambient concentrations and median concentration for each chemical.
4. List the range of measured downgradient ambient concentrations and median concentration for each chemical.
5. List the general or specific (if applicable) location of the sampling point(s) used to determine the maximum measured concentration.

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

		Upgradient Ambient Concentrations			Downgradient Ambient Concentrations				
Chemical	Suspended Release Source	a/ Range	Median	# of Samples	a/ Range	Median	# of Samples	Location of Maximum Measurements	Comments
Trichloroethylene	Prior facility release	BDL b/	BDL	6	BDL-1.8 ug/l	1.2 ug/l	3	GW Monitoring Wells #2, 3, 4	Release of 1,200 gallons on 8/5/81
Arsenic	Naturally occurring background	2-7 ug/l	3 ug/l	5	1-8 ug/l	3 ug/l	4	Private well at Johnson Residence	Residence is 2 km E of facility

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a/ If available, in some cases only a single data point may be available.

b/ BDL = Below detection limits.

water for drinking water, agricultural, and industrial uses. If the ground water in the vicinity is not already being used for drinking water, the applicant has two options for determining whether water quality is sufficient for drinking water use. One option would be for the applicant to assume that the ground water is suitable for drinking water and attempt to demonstrate that predicted levels of contamination would not pose a risk even if the water were used for drinking. If the applicant suspects that the ground water is unsuitable for drinking, then the second option would be for the applicant to compare existing levels of background contaminant concentrations to available drinking water standards and guidelines to determine the suitability of the ground water for drinking water purposes. EPA's Office of Drinking Water has developed Primary and Secondary Drinking Water Standards and Health Advisories for permissible concentrations of specific inorganic and organic contaminants in drinking water. These standards are presented in Appendix C. EPA has also developed health-based water quality criteria for surface waters under the Clean Water Act. These criteria can be adjusted to apply to ground water by factoring out ingestion of contaminated aquatic organisms. These adjusted water quality criteria are also presented in Appendix C.

Worksheet 4-3 provides instructions and a format for comparing ground-water quality to existing EPA standards relevant for determining the suitability of ground water for drinking. The suitability of ground water for agricultural and industrial uses will vary by industry and by type of agricultural use. Consequently, professional judgment should be exercised to determine the suitability of a ground-water resource for these uses. In some cases, local agricultural extension service agents may be able to provide some guidance on suitability of ground water for agricultural use.

Treatability of ground water may, in some instances, be an important consideration in assessing the potential future uses of a ground-water resource. If the existing quality of ground water is sufficient for drinking water use, the applicant need not evaluate treatability. If the existing quality of ground water precludes the use of ground water for drinking water, agricultural, or industrial use, however, the applicant should evaluate whether available treatment technologies could make such uses possible. Available treatment technologies include carbon adsorption, ozonation, air stripping, desalination, and ion exchange. A brief overview of treatment technologies is included in Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy.[33] Again, the applicant will need to exercise professional judgment in evaluating the treatability of ground water. Worksheet 4-4 provides a format and instructions for evaluating the treatability of ground water.

The **maximum sustained yield** of an aquifer will also help determine future potential uses of a ground-water resource. EPA's draft ground-water classification guidelines estimate that a yield of 150 gallons per day is the

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[33] EPA, Guidelines for Ground-Water Classification under the EPA Ground-Water Protection Strategy, Final Draft, Office of Ground-Water Protection, December 1986. See Appendix E of this reference for a list of recent papers and analyses of treatment technologies.

WORKSHEET 4-3

COMPARISON OF BACKGROUND CHEMICAL CONCENTRATIONS IN GROUND WATER TO DRINKING WATER STANDARDS AND GUIDELINES

Facility ID: __________

Date: __________

Analyst: __________

Quality Control: __________

INSTRUCTIONS:

1. List all background chemicals.
2. For each chemical, list the median and maximum ambient concentrations.
3. List any relevant EPA standards and the source of the standard (i.e., MCL, MCLG, WQC).a/
4. Under the comments section, indicate whether the background concentrations exceed or fall below the standards or whether no standards are available.

Chemical	Median Concentration	Maximum Concentration	Relevant EPA Standard	Source of the Standard	Comments
Cadmium	.004 mg/l	.005 mg/l	.01 mg/l	MCL, WQC	both values fall below the standard
Toluene	.2 mg/l	1 mg/l	15 mg/l	WQC	both values fall below the standard

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a/ MCL = maximum contaminant level
MCLG = maximum contaminant level goal
WQC = water quality criteria

WORKSHEET 4-4

TREATMENT OPTIONS FOR REDUCING CONTAMINANT LEVELS

INSTRUCTIONS:

1. List use under consideration.
2. List all contaminants at levels exceeding those permissible to support the use.
3. For each contaminant, identify the necessary contamination reduction and potential methods to achieve the reduction.

Facility ID: ____________
Date: ____________
Analyst: ____________
Quality Control: ____________

Potential Future Use: Drinking Water

Contaminant	Concentration		Treatment Options	Level of Contaminant Treatment		
	Current Maximum	Necessary for Potential Use		Reduction	Duration	Treatment Costs
TDS	12,000 mg/l	1,200 mg/l	Desalination	90%	Permanent	$/gallon
Toluene	28 mg/l	Less than 15 mg/l, WQC	Carbon Adsorption	50%	As needed	
			Air Stripping	50%	As needed	

minimum yield necessary to meet the water needs of a typical household.[10J] Much higher yields would generally be required to support agricultural, industrial, or municipal uses of ground water. In evaluating the quantity of ground water in the area in Section 4.1.2, the applicant should have already estimated the maximum sustainable yield of the aquifer. The applicant should exercise professional judgment in determining what potential uses of ground water can be supported by the potential yields of the aquifer.

In addition to hydrogeologic, physical and chemical ground-water characteristics such as ground-water quality, potential yield, and treatability, the applicant should also consider land use and ground-water use restrictions and demographic factors in evaluating future uses of ground water. State or community water laws may, for example, limit total withdrawal from an aquifer or may place restrictions on the use of land overlying a vulnerable aquifer. Regional and local zoning laws may also restrict or control the use of land overlying an aquifer. Demographic factors, such as population growth and housing patterns may also influence ground-water use. For example, if undeveloped land overlying an aquifer is zoned for residential use, but the population in an area is projected to remain at existing levels, future use of the ground water for residential drinking water may be unlikely. Conversely, in areas undergoing rapid development, zoning patterns may also change rapidly. Existing farmland may be developed for residential or commercial use, with a possible subsequent change in ground-water use from agricultural to domestic use.

It is difficult to determine future use of ground water with any great certainty. State or regional water authorities, private and public water supply system officials, and regional and local land use planning agencies may be able to provide useful information. A narrative summary of future uses of ground water should be submitted as part of the variance application. The summary should demonstrate that the applicant has carefully evaluated the future domestic, agricultural, or industrial use of the ground water and should include a rationale and supporting evidence for rejecting or selecting each future use.

4.2 SURFACE WATER USE AND QUALITY CHARACTERISTICS

Existing quality of surface water and current and future uses of surface water must be considered by the applicant in evaluating the potential risks to human health and the environment posed by a tank system release. Characterizing existing quality and current and future uses of surface water is required to: (1) establish the baseline background conditions for evaluating risks to human health and the environment; and (2) determine water uses for identifying potential exposure pathways in surface water. For example, if a nearby lake is used extensively for swimming, the applicant would need to consider the possibility of dermal contact exposures in identifying exposure pathways in Chapter 5.

[10J] EPA, Guidelines for Ground-Water Classification under the EPA Ground-Water Protection Strategy, Final Draft, Office of Ground-Water Protection, December 1986, p. 45.

In assessing surface water use and quality characteristics, the applicant should evaluate those surface waters that might possibly be contaminated by a release based on the hydrogeologic characterization discussed in Chapter 3. For example, it is unlikely that surface waters upgradient and distant from the facility would be contaminated by a release. The applicant should consider the possibility of surface water contamination via both ground-water flow and surface runoff.

As part of the Clean Water Act regulatory program, state environmental agencies in many states may have already evaluated the existing quality of surface waters in the area and evaluated current and future uses. Many state environmental agencies have assigned "designated uses" to surface water bodies in their state as part of the process of developing water quality standards under Section 303 of the Clean Water Act. "Designated uses" of surface water bodies include protection and propogation of fish, shellfish, and wildlife; recreational uses; agricultural and industrial use; use as a public water supply; and navigational uses. A water body may have multiple designated uses. In assigning designated uses to a surface water body, regulatory agencies generally consider the highest attainable use to which a surface water body could be put, taking into account existing water quality and the potential for improving water quality. Therefore, designated uses may include both current and potential future uses. The biological, physical, and chemical data upon which designated uses are based are often contained in specific documents referred to as "water body surveys and assessments." These documents can be useful sources of surface water quality and use information. An important first step in evaluating quality and uses of surface waters is to contact the appropriate state environmental agency or Regional EPA office responsible for water programs to identify and obtain any available information on surface waters in the surrounding area.

The following subsections explain what types of information relating to surface waters may be required and how this information may be used in evaluating the quality of surface waters, identifying current uses, and predicting future uses.

4.2.1 Existing Quality of Surface Water

Surface water quality parameters include both physical and chemical parameters. Physical parameters of surface water quality, such as temperature, turbidity, and reaeration rates will already have been measured in evaluating the hydrogeologic characteristics of surrounding surface water. Consequently, this subsection discusses the chemical parameters rather than the physical parameters necessary to evaluate surface water quality.

If available, the applicant should provide data for conventional surface water quality parameters, such as suspended solids, nutrients (e.g., nitrogen and phosphorous), sediment oxygen demand, salinity, hardness, alkalinity, pH, fecal coliform, and dissolved solids. Data on these parameters may be helpful in evaluating potential surface water uses. For example, highly saline water may be unsuitable for drinking. In many cases, state or local environmental agencies may already have obtained current data for these parameters for specific surface water bodies. If such data are unavailable, water quality testing will be required. The results of water quality testing should be submitted in a clear, concise format along with necessary supporting documentation.

For potentially toxic contaminants, the applicant should follow the same basic procedure used for evaluating background ground-water quality. For each surface water body that could potentially be contaminated by a release, concentrations of suspected RCRA Appendix VIII hazardous constituents should be determined. Consideration should be given to both point sources and non-point sources of contamination. The purpose of evaluating the contamination from these sources is to establish a baseline for evaluating a tank system release. For example, if existing discharges of contaminants into a surface water body greatly exceed the projected discharge resulting from a tank system release, then the incremental risk posed by the tank release may be negligible compared to existing conditions. Conversely, the same projected tank release discharged into a pristine trout stream may be unacceptable. Any point sources of pollutant loading to surface waters should be identified on an appropriately scaled map. The point sources should include:

- discharges from industrial facilities;
- discharges from publicly owned treatment works (POTW); and
- past waste discharges.

The applicant should submit a table, Worksheet 4-5, that includes the name of each point source and the water body into which the point source discharges. The National Pollutant Discharge Elimination System (NPDES) permit number of each point source should also be included in this table. If available, data on discharge rates, load allocations, permit discharge conditions, and mixing zones should be provided and discussed in a separate summary. Reports containing NPDES permit compliance and permit application monitoring data should be referenced if these reports contain information on the selected indicator or background chemicals.

Any non-point sources of pollution to surface waters that may affect the variance decision should also be discussed. The permit applicant should submit information on:

- urban storm runoff;
- agricultural runoff;
- ground-water infiltration; and
- other RCRA facilities.

Actual monitoring data may be submitted along with any contaminant load calculations based on modeling results, if they are applicable. Worksheet 4-6 provides instructions and a format of presenting the results of the background surface water quality characterization.

4.2.2 Current Uses of Surface Water

Surface waters have many potential uses and a particular surface water body may have multiple uses. Important uses of surface waters include:

- recreation (swimming, boating, and fishing);
- protection and propagation of fish and other aquatic life (including areas of special ecological concern);

WORKSHEET 4-5

SURFACE WATER CONTAMINATION SOURCES

INSTRUCTIONS:

1. List all potential contamination sources.
2. For each source list the water body into which it discharges.
3. If applicable and available, list discharge rate, contaminant load allocations, and NPDES permit number.

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Source	Water Body	Discharge Rate m3/day	Contaminant Load Allocations	NPDES #	Comments
C and C Electroplat.	Green River	29,000 m^3/day	Copper 20 g/day	NJ50721	
			Zinc 45 g/day		
Smithville POTW	Green River	18,000 m^3/day			

WORKSHEET 4-6

MEASURED SURFACE WATER CONCENTRATIONS OF BACKGROUND CHEMICALS

INSTRUCTIONS:

1. List all surface water bodies in the area that could potentially be contaminated by a release.
2. For each water body list all selected background chemicals.
3. For each chemical listed, identify the release source.
4. List the range and median measured ambient concentrations for each water body.
5. Identify the sampling location(s) used to determine the maximum concentration.

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Water Body	Chemical	Suspected Release Source	Ambient Concentrations Range	Ambient Concentrations Median	Number of Samples	Location of Maximum Measurement	Comment
Bear Creek	Phenols	Chemtron plant	1-5 mg/l	1.3 mg/l	3	Sampling Pt. #3	
	Zinc	Natural background	1-6 mg/l	2 mg/l	3	Sampling Pt. #2.	

- agricultural and industrial water supply; and
- public water supply.

Identifying uses of surface water is an important initial step in identifying potential exposure pathways and identifying potentially sensitive ecological areas, such as fish spawning grounds or endangered species' critical habitats. The information gathered on surrounding water use will be helpful in making sure that the applicant does not overlook any potential exposure pathways or sensitive aquatic environments.

To determine current uses of water, state and local government agencies, such as water authorities, and natural resource management agencies should be contacted. In remote areas, nearby residents may also be able to supply useful information. If a surface water body has been assigned a "designated use" the applicant should note the designated use or uses and determine which of the designated uses are considered to be current uses. A list of potential sources for information on current uses of surface water is provided in Appendix B. A summary of current uses should be provided on Worksheet 4-7.

4.2.3 Future Uses of Surface Water

Future uses of surface water depend not only on the hydrogeologic, biological, and chemical characteristics of the surface water but also upon legal and demographic factors. As in the analysis of future ground-water uses, it can generally be assumed that current uses of surface waters will continue in the future. For example, if a surface water body currently supports recreational uses such as sport fishing and swimming, it is likely that these uses will continue.

Physical, hydrologic, biological, and chemical characteristics all affect the potential uses of a surface water body. For example, some species of gamefish, such as trout, require fast moving relatively clear, cool water with high concentrations of dissolved oxygen. Recreational uses of a surface water body such as swimming and boating depend greatly on physical characteristics such as depth, size, temperature, and water quality. EPA and many state environmental agencies have already developed guidance on evaluating potential uses of surface water bodies based on physical, chemical, and biological characteristics. These guidance materials have been developed to support state efforts to establish "designated uses" for surface water bodies under the Clean Water Act. One useful document is the Technical Support Manual for Conducting Use Attainabilty Analyses.[11]

While physical, chemical, and hydrologic characteristics of a surface water body may determine what future uses are possible, demographic trends, land use controls, government regulatory efforts and water use controls must also be considered in identifying potential future uses. For example, although existing water quality and physical characteristics of a surface

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[11] EPA, Technical Support Manual for Conducting Use Attainability Analyses, Office of Water.

WORKSHEET 4-7

SUMMARY OF CURRENT AND FUTURE USES OF SURFACE WATERS IN THE AREA

INSTRUCTIONS:

1. List all surface water bodies that could potentially be contaminated by a release.
2. Provide a brief description of the water body (e.g., lake, pond, reservoir).
3. For each water body, list the distance from the release source.
4. For each water body listed, identify current and future uses (e.g., agricultural, recreational, municipal, industrial).
5. Provide any additional useful information under comments.

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Surface Water Body	Description	Distance From Release Source	Current Uses	Future Uses	Comments
Bear Creek	Small tributary of Green River	1.2 km	Recreation: fishing, swimming	Recreation: fishing, swimming	
Lake George	Artificial 40 acre lake	1.4 km	None	Recreation: fishing, swimming, boating	Planned residential community to be constructed around the lake.
Green River	Major regional waterway	2.5 km	Industrial: cooling water; municipal water supply	Recreation: fishing	Fish stocking program is underway along with streambed improvements.

water body may support recreational use, if the water body is inaccessible and removed from a population area, such use may be unlikely. Water usage laws and restrictions may also place limits on the future use of a surface water body for agricultural, recreational, or industrial purposes. Finally, although existing water quality may not be sufficient for certain uses, pollution reduction efforts or physical alterations to a water body, such as dredging, may be planned or underway that could significantly affect future uses.

An applicant should submit a narrative summary of current and potential future uses of surface waters. For each surface water body identified in Chapter 3, the applicant should provide a rationale and appropriate evidence to support the use or uses identified for the particular water body. If a surface water body in the surrounding area has been assigned a designated use by the state or EPA, the applicant should indicate the designated use or uses on Worksheet 4-7. If a surface water body does not have an assigned designated use, the applicant should use the information provided in this document and in available designated use classification guidance documents to determine future uses. A summary table of current and future uses, as shown in Worksheet 4-7, should be provided.

4.3 CURRENT AND FUTURE USES OF SURROUNDING LAND

To some extent, current and future uses of surrounding land will have already been determined in identifying current and future uses of ground water and surface water. The purpose of obtaining information on the current and future uses of surrounding land in this section is to characterize surrounding agricultural, commercial, and residential land use and to identify any ecologically sensitive areas that could be adversely affected by a release of hazardous contaminants. Such ecologically sensitive areas may include:

- state, federal, and local parks;
- wildlife refuges;
- wilderness areas; and
- critical habitats for endangered and threatened species.

Agricultural, commercial, and industrial land uses can usually be identified by contacting local land use regulatory authorities, such as zoning boards, and reviewing appropriate land use plans and maps. Identifying ecologically sensitive areas may be more difficult. While some of these ecologically sensitive areas may be marked on U.S. Geological Survey topographic maps or other maps, many may not be marked. In particular, the location and boundaries of some critical habitats are not published or made readily available to the public.

To verify the existence of ecologically sensitive areas and to identify areas under consideration for protection, relevant state and federal government agencies, such as state and federal park agencies, fish and wildlife agencies, and private conservation groups, such as The Nature Conservancy, should be contacted. A list of potential agencies and organizations that may be able to provide information on surrounding land use is included in Appendix B of this technical resource document.

The applicant should submit a narrative description of current and future uses of surrounding land. Information on land use collected to determine future uses of ground water and surface water should be included. The use of all land in the immediate surrounding area should be carefully described. For each discrete parcel of land in the area, the applicant should describe current use and potential future uses. The applicant should devote special attention to describing any ecologically sensitive habitats in the surrounding area. Two maps of the surrounding area, one identifying current land use and another identifying future land uses, should also be provided.

CHAPTER 5

IDENTIFYING EXPOSURE PATHWAYS AND ESTIMATING EXPOSURE POINT CONCENTRATIONS

The applicant for the risk-based variance could demonstrate no substantial hazard in one of two ways: (1) if current or future exposure pathways do not exist; or (2) if current or future exposure point concentrations do not pose a substantial hazard to human health or the environment. This chapter describes methods for identifying current and future potential exposure pathways and estimating potential environmental concentrations of indicator chemicals if any exposure pathways exist. Because the applicant must assess the risk associated with potential worst case releases, it is necessary to identify if, how, and when exposure would take place. Environmental fate and transport models[1] are generally used for these determinations. Modeling may be necessary to demonstrate that no exposure pathways exist (e.g., by showing that attenuation mechanisms result in a situation such that contaminants never reach points of human uptake (i.e., potable wells)). In some situations, however, modeling will not be necessary. For example, a detailed hydrogeolgic investigation and qualitative assessment of site conditions and exposure pathways may be sufficient to demonstrate that no exposure pathways exist (e.g., due to an impermeable subsurface formation preventing transport of contaminants to ground water, and the location of the facility in an isolated, naturally contained area (thereby preventing surface water contamination)).

Many models, ranging widely in sophistication, data input requirements, cost, and reliability, are available. Consideration should be given to the complexity of the site and the environment, the precision needed, and the time available for analysis. Much literature exists which describes the various available models and provides guidance in selecting modeling techniques that are appropriate for site-specific conditions.[2] It should be recognized early, however, that the uncertainty associated with modeling results can be significant. Thus, considerable expertise is frequently necessary to interpret hydrogeologic and exposure assessment information.

At some sites, background chemical contamination is significant and must be accounted for in the hazard evaluation. Background is defined here as chemical contamination due to a source other than a release from the hazardous waste tank system. Background can be either "natural," as in the case of certain inorganics (e.g., arsenic), or from various anthropogenic sources (e.g., industrial point sources, other uncontrolled waste sites, agricultural pesticide applications). In either case, background concentrations, determined in Chapter 4, must be added to the estimated exposure point concentrations that would result from a tank release. As discussed in Chapter 4, it is important that background concentrations of chemicals that have not been included as indicator chemicals, and that may not even be present in the waste, be considered in the overall hazard evaluation. This inclusion is necessary because the existing quality of the particular environmental media being evaluated may be approaching or may have already exceeded the threshold that determines whether the environmental media is posing a substantial present or potential hazard to human health or the environment. Therefore, if chemicals with high background concentrations were not included as indicator chemicals, they must be included in the analysis at this point. Although sampling of soil, water, and air is essential in determining background concentrations, information resources such as the U.S. Geological Survey, the Soil Conservation Service, the Army Corps of Engineers, and state environmental or land use agencies may also be helpful in providing data and information on sources of background contamination.

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[1] For the purpose of this discussion, the term "model" refers to any estimation technique; these techniques include simple equations as well as complex computer programs.

[2] A current review of existing models can be found in the following document: EPA, Superfund Exposure Assessment Manual, Draft, Office of Emergency and Remedial Response, January 1986.

The methods for estimating exposure point concentrations should be applied to the selected indicator chemicals. Exhibit 5-1 diagrams the activities involved in estimating exposure point concentrations. The first task is a detailed exposure pathway analysis (Section 5.1). The second is estimation of the highest short- and highest long-term concentrations for each indicator chemical at each exposure point (Section 5.2). The concentrations derived will then be the inputs to Chapters 6 and 7 (estimation of human hazard and environmental hazard, respectively). Worksheets are provided as a means for organizing and documenting the data collected for estimating exposure point concentrations. Filling in these worksheets will not be sufficient to complete the quantitative analyses required. Rather, they serve to direct and focus the analysis so that the results can be used directly in later steps of the hazard evaluation. All procedures, assumptions, and calculations used to develop concentration estimates must be clearly documented in a format that will facilitate review.

5.1 IDENTIFY EXPOSURE PATHWAYS

This section describes an approach for identifying current and future potential exposure pathways at a hazardous waste tank site.[3] An exposure pathway consists of five necessary elements:

(1) source (hazardous waste tank systems in this case);

(2) mechanism of chemical transport to the environment (usually leaching and runoff, but often also volatilization);

(3) environmental transport medium (e.g., ground water, surface water);

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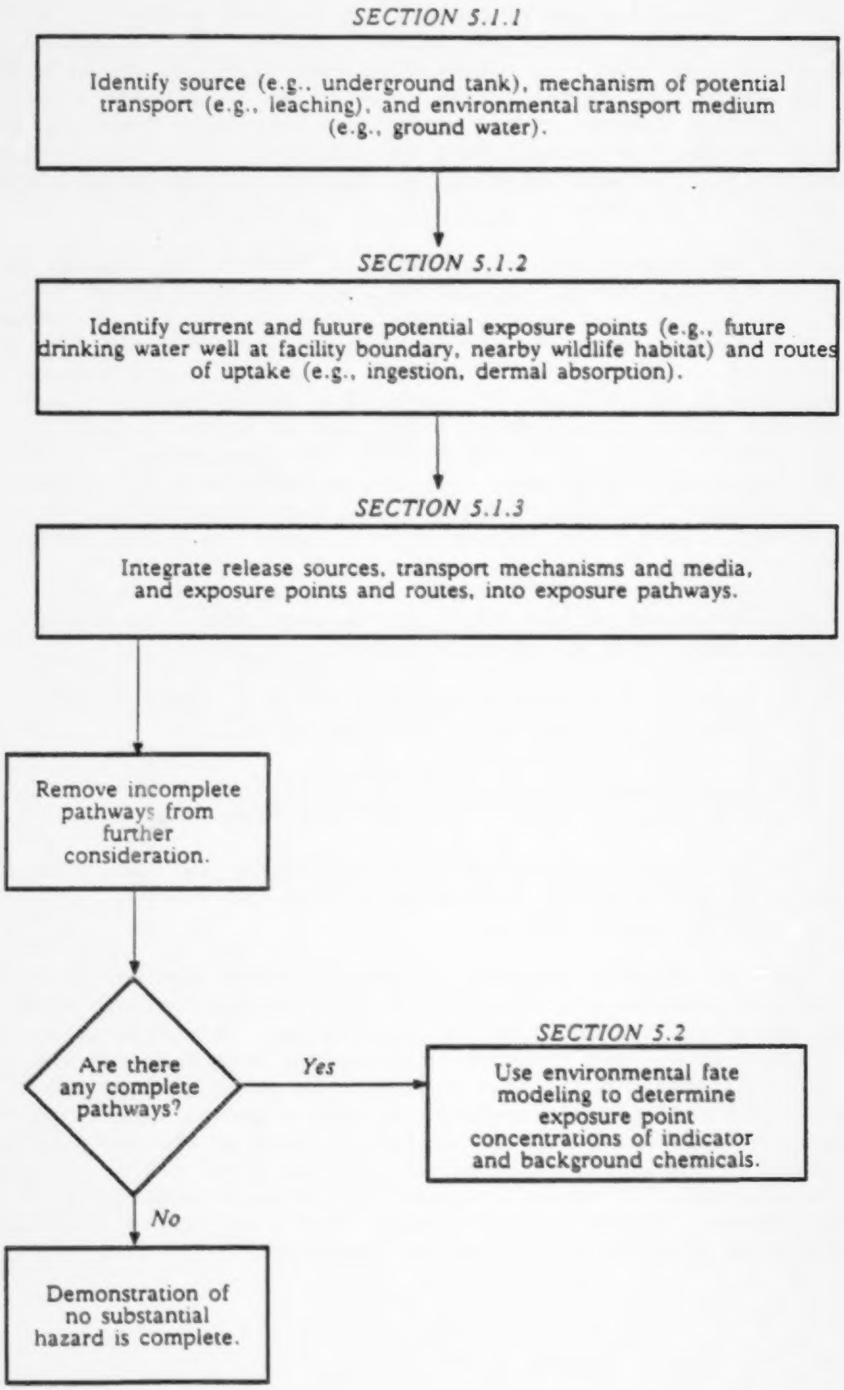
[3] Also, see the following: EPA, Permit Applicants' Guidance Manual for Exposure Information Requirements Under RCRA Section 3019, Office of Solid Waste, July 3, 1985.

Exhibit 5-1
OVERVIEW OF EXPOSURE POINT CONCENTRATION ESTIMATION


SECTION 5.1.1
Identify source (e.g., underground tank), mechanism of potential transport (e.g., leaching), and environmental transport medium (e.g., ground water).
SECTION 5.1.2
Identify current and future potential exposure points (e.g., future drinking water well at facility boundary, nearby wildlife habitat) and routes of uptake (e.g., ingestion, dermal absorption).
SECTION 5.1.3
Integrate release sources, transport mechanisms and media, and exposure points and routes, into exposure pathways.
Remove incomplete pathways from further consideration.
Are there any complete pathways?
Yes
SECTION 5.2
Use environmental fate modeling to determine exposure point concentrations of indicator and background chemicals.
No
Demonstration of no substantial hazard is complete.

(4) point of potential human or environmental contact with the contaminated medium (i.e., the exposure point); and

(5) human or environmental exposure route (e.g., drinking water ingestion) at the exposure point.

Exhibit 5-2 illustrates the elements of an exposure pathway. Each pathway, therefore, describes a unique mechanism by which a population, an individual, a wildlife habitat, etc., is potentially exposed to contaminants originating from a facility. The overall risks posed by a facility are a composite of the set of individual pathway risks. Risks for individual pathways, however, may not always be additive because they may represent risks to different populations (e.g., ground water may be used by one population while surface water is used by another).

The risk assessment process is based on concern for both current and future risk to individuals, populations, and the environment. Therefore, two exposure points that must be determined and evaluated are the geographic points of highest current and highest future individual exposure for each combination of release source, transport mechanism, and transport medium. These exposure points will be the geographic locations where human or environmental receptors are potentially exposed to the highest predicted chemical concentrations. For the highest future exposure, the farthest point from the tank system or cluster that can be considered is the particular facility boundary that would result in the highest potential future exposure, unless it can be shown that future exposure would be higher outside the facility boundary. To obtain a complete understanding of the potential risks associated with a potential release, current and future exposure points with lower exposure concentrations must also be evaluated. In summary, there are essentially three types of exposure points:

(1) current locations of highest potential exposure (e.g., existing private wells near the site);

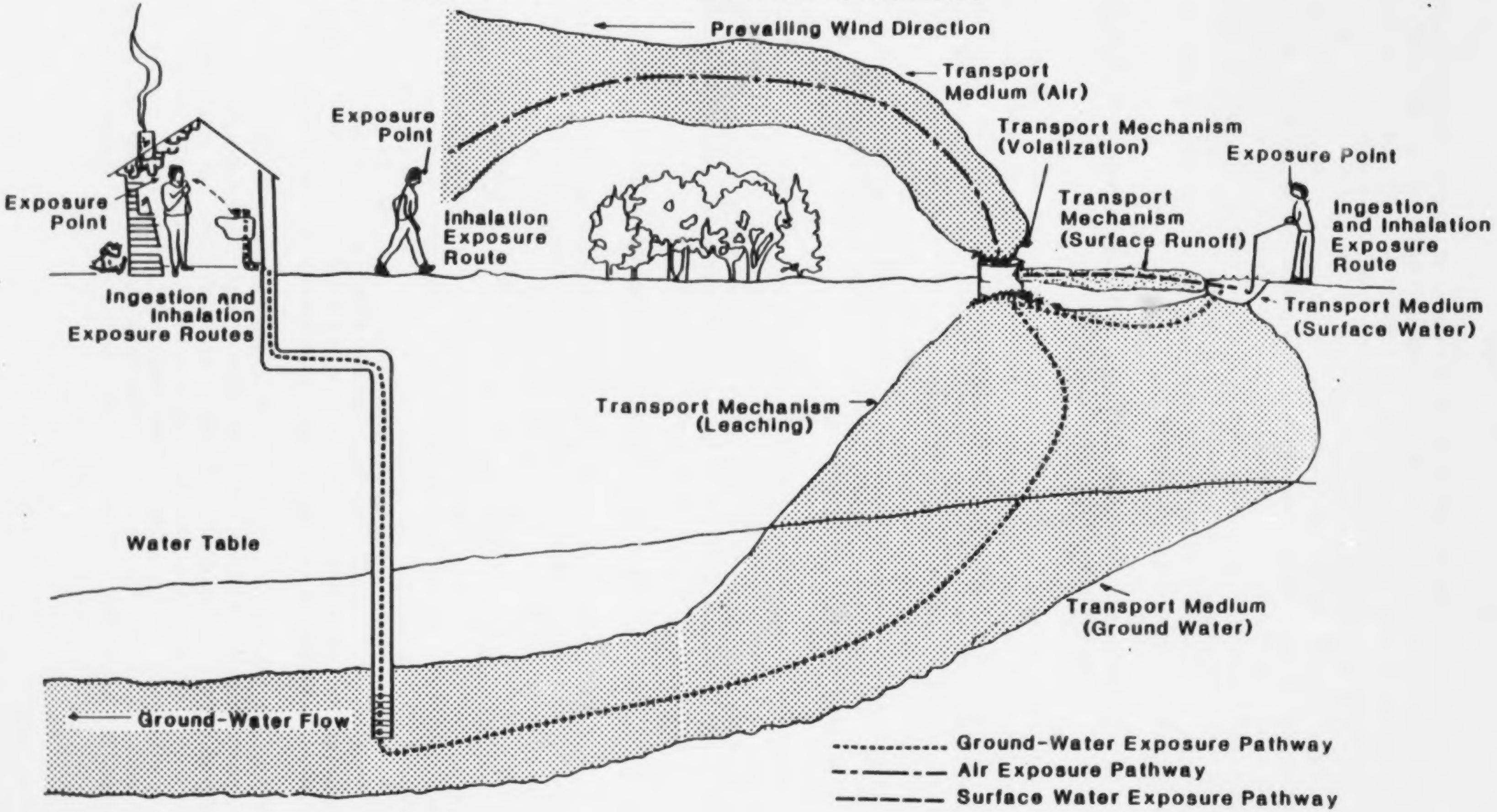
(2) future locations of highest potential exposure (e.g., hypothetical well on the facility boundary); and

(3) all other current and future potential exposure points (e.g., existing distant wells used for a local water-supply system).

To identify possible exposure pathways, current and future activity patterns on and near the site should be defined and combined with chemical release source and transport media information. This task is accomplished using a qualitative, yet systematic, procedure that requires the judgment and experience of professionals in fields such as public health and wildlife biology. Because chemical transport is more rigorously analyzed for the estimation of exposure point concentration phase of the exposure assessment (Section 5.2), the initial list of exposure pathways can be modified as the analysis proceeds. If there are questions or uncertainties about a possible exposure pathway, it should not be eliminated from the analysis until the exposure point concentration phase is completed.

Exhibit 5-2

ILLUSTRATION OF TYPICAL EXPOSURE PATHWAYS


Prevailing Wind Direction
Transport Medium (Air)
Transport Mechanism (Volatization)
Exposure Point
Exposure Point
Inhalation Exposure Route
Exposure Point
Ingestion and Inhalation Exposure Routes
Transport Mechanism (Surface Runoff)
Ingestion and Inhalation Exposure Route
Transport Medium (Surface Water)
Transport Mechanism (Leaching)
Water Table
Transport Medium (Ground Water)
Ground-Water Flow
Ground-Water Exposure Pathway
Air Exposure Pathway
Surface Water Exposure Pathway

The analysis described here is a first-cut organization of the relevant site information so that major exposure pathways can be defined. It is not intended as a time-consuming task in the overall hazard evaluation process. Modeling will help confirm the important exposure pathways (i.e., the exposure points with high exposure concentrations). The first three elements of the exposure pathway analysis listed previously (i.e., source, transport mechanism, and transport media) are discussed below in Section 5.1.1. The last two elements of the exposure pathway analysis (i.e., exposure point and exposure route) follow in Section 5.1.2. These five elements are then integrated into exposure pathways in Section 5.1.3. Finally, Section 5.1.4 provides guidance on determining the presence of sensitive populations and sensitive environmental receptors.

5.1.1 Determine Possible Chemical Release Sources, Transport Mechanisms, and Transport Media

Possible release sources for a site are ruptures or leaks from the systems or components being considered for the risk-based variance from secondary containment; the transport mechanisms are usually runoff, leaching, and volatilization; and the four transport media are soil, surface water, ground water, and air. Much of the information for release sources, transport mechanisms, and transport media has already been gathered, as described in Chapters 2, 3, and 4, and it may only need to be compiled here. In addition, Exhibit 5-3 provides guidance on determining common release sources, transport mechanisms, and transport media.

Use the first three columns of Worksheets 5-1 and 5-2 to summarize the results of the initial release analyses. At this point, combinations of release source, transport mechanism, and transport medium for a site (i.e., the first three components of an exposure pathway) have been identified. The exposure points for each must now be determined.

5.1.2 Identify and Characterize Exposure Points and Routes

Again using Worksheets 5-1 and 5-2, identify the current location of highest potential exposure to humans and the environment. These exposure points may be either inside (e.g., workers) or outside (e.g., residential area) the facility boundary. Next, identify the future location of highest potential exposure. These locations will usually be at the facility, tank system, or tank system component boundary. The farthest point, however, that can be considered for future exposure is the particular facility boundary that results in the highest potential individual future exposure, unless it can be shown that future exposure would be higher outside the facility boundary. This point will usually be the nearest downgradient boundary. Finally, identify for each combination of release source, transport mechanism, and transport medium all other current and future potential exposure points.

Consideration of all potential exposures in this way (i.e., highest current, highest future, and all others) ensures that significant risks are not ignored. For example, assume a facility does not have any current on-site ground-water exposure points. If the facility boundary is not expected to be a significant future ground-water exposure point (e.g., due to a thick layer of rock overlying the aquifer), then off-site locations may provide the only potential exposures. These off-site exposures may result in significant risk.

EXHIBIT 5-3

COMMON RELEASE SOURCES, TRANSPORT MECHANISMS, AND TRANSPORT MEDIA

Transport Medium	Transport Mechanism	Release Source
Surface Water	Surface runoff	Contaminated surface soil
	Episodic overland flow	Overflows, spills, leaks Catastrophic release
	Ground-water seepage	Contaminted ground water
Ground water	Site leaching	Leaking tank systems Contaminated soil
Soil	Site leaching	Leaking tank systems
	Surface runoff	Contaminated surface soil
	Episodic overland flow	Overflows, spills, leaks Catastrophic release
	Fugitive dust generation/deposition	Contaminated surface soil
	Tracking	Contaminated surface soil
Air	Volatilization	Overflows, spills, leaks Catastrophic release Contaminated surface soil Contaminated wetlands
	Fugitive dust generation	Contaminated surface soil

WORKSHEET 5-1

POTENTIAL HUMAN EXPOSURE PATHWAYS

INSTRUCTIONS:

1. List all release sources, transport mechanisms, and transport media (use additional worksheets if necessary).
2. Describe the nature of the exposure point and its location with respect to release source (e.g., nearest residence to volatilization release site, 300 feet NW). Attach a map indicating location of system and exposure points.
3. List exposure route (e.g., inhalation, ingestion).
4. Report the number of people potentially exposed at the exposure point.
5. Indicate if exposure pathways are complete (i.e., where release source, transport mechanism, transport medium, exposure point, and exposure route all exist).

Facility ID: ______________

Cluster/Tank System: ______________

Date: ______________

Analyst: ______________

Quality Control: ______________

Release Source	Transport Mechanism	Transport Medium	Exposure Point	Exposure Route	Size of Population	Pathway Complete?
Underground Tank 1	Leaching	Ground water	Wells at nearest residences	Ingestion of drinking water	50	Yes
Underground Tank 1	Leaching	Ground water	Facility boundary (future)	Ingestion of drinking water a/	? (future)	Yes(future)
Aboveground Pipes	Volatilization	Air	Nearest residences (includes day-care center)	Inhalation	50	Yes
Onground Tank 3	Volatilization	Air	Trailer park (0.5 miles south of site)	Inhalation	600	Yes

a/ Hydrogeologic investigation has determined that the ground water is potable.

WORKSHEET 5-2

POTENTIAL ENVIRONMENTAL RECEPTOR EXPOSURE PATHWAYS

INSTRUCTIONS:

1. List all release sources, transport mechanisms, and transport media (use additional worksheets if necessary).
2. Describe the exposure point.
3. List the exposure route (ingestion, respiration).
4. Describe what is affected at the exposure point (e.g., species list or community description).
5. Attach a complete list of species, population levels, value (if applicable) and structures if not identified on worksheet.

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Source	Transport Mechanism	Transport Medium	Exposure Point	Exposure Route	Species/Community/ Structures	Pathway Complete?
Underground Tank 1	Leaching	Ground water	Tree farm	Root absorption	White pine	Yes
		Spring	Watering hole	Ingestion	Beech-Maple forest	Yes
			Aquatic habitat	Ingestion, respiration	Class I trout stream	Yes
				Animal, Food Chain		
In-ground Tank 2	Leaching	Ground water	Underground pipes	Surface contact	Water supply lines	Yes
					Gas supply lines	

The highest short- and highest long-term exposures must be considered for each exposure point. (Short- and long-term are addressed in greater detail in Section 5.2.) In addition, include any locations with the potential for exposure of populations (e.g., public drinking water supplies, shopping centers, industrial parks, wildlife refuges) or sensitive populations that may be at special risk (e.g., schools, hospitals, endangered habitats). (Sensitive populations are considered in greater detail in Section 5.1.4.) Determine the number of people as well as the number and type of environmental receptors (e.g., wildlife, habitats) potentially affected at each exposure point and record the basis for the estimate.[a] Finally, determine the probable routes of exposure at each exposure point (e.g., drinking water ingestion, fish ingestion).

The distinctions between human exposure points and environmental receptor exposure points are of critical importance. In particular, human exposure points refer to locations of human activity, whereas environmental receptor exposure points refer to wildlife and their habitats, agricultural products, ecologically vital areas, historical sites, other human-made structures, protected parklands, and renewable resources. Environmental receptors may also include underground cables, septic fields, foundations or structures of archeological or esthetic value which may come in contact with contaminated water or vapors released from a contaminant plume. For the purpose of identifying the potentially affected environmental receptor, a complete list of species (plant and animal), population estimates for each species (including migrants and threatened or endangered species), identification of sensitive species (most sensitive to toxic action of chemicals), commercial or recreational value of affected area over the total duration of exposure, and a list of physical structures contacted should be included in Worksheet 5-2. The species of wildlife present, and their numbers and interactions, will be examined in more detail in Section 7.3.

Guidance for identifying exposure points and routes is given below for each of the four transport medium. Typical exposure points and routes for these media are summarized in Exhibit 5-4. This exhibit can be used as guidance for determining exposure points and routes, but note that this determination requires a site-by-site analysis and the possibility of other exposure points and routes must be considered for each site.

Surface Water Exposure. The significant current and future potential exposure points for surface water pathways depend on current and future downstream uses of the water. Potential withdrawal points and areas of in-stream use must be considered. Withdrawal points to be considered include

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[a] Although individual risk is of primary concern, the number of people or environmental receptors is important for providing additional information in "borderline" demonstrations. For example, if estimated individual potential exposure through a public water supply is low but highly uncertain due to complex exposure pathways, then the existence of a large potentially exposed population may indicate the need for greater caution when deciding whether to allow a variance. In the event exposure is underestimated, it would be more difficult to provide an alternative water supply for a large population than for a small population.

EXHIBIT 5-4

TYPICAL PRESENT AND POTENTIAL EXPOSURE PATHWAYS

Transport/Exposure Medium	Typical Present or Potential Exposure Point	Major Exposure Route
Surface water	Withdrawal point for potable use	Ingestion, dermal, inhalation
	Withdrawal point for agricultural use	Ingestion (food), dermal, inhalation
	Withdrawal point for other use (e.g., industrial)	Dermal, inhalation
	Nearest point for swimming/contact sports	Ingestion, dermal
	Nearest point for fishing	Ingestion (food)
	Aquatic habitat	Ingestion/respiration, dermal, food chain
	Settling basins (on-site)	Ingestion, dermal, inhalation (wildlife)
Ground water	Potable well (private or public)	Ingestion, dermal, inhalation
	Agricultural well	Inhalation, ingestion (food), dermal
	Well for other uses (e.g., industrial)	Inhalation, dermal
	Basement infiltration	Inhalation
	Forage plants	Ingestion, food chain
	Spring	Ingestion, dermal, inhalation
Soil	On-site	Dermal, ingestion
	Immediately adjacent to site	Dermal, ingestion
	Nearest cropland	Ingestion (food)
Air	Nearest residence/habitat	Inhalation
	Nearest population magnet (e.g., shopping center, school, industrial park)	Inhalation
	Other residence/population at point of highest concentration	Inhalation
	On-site	Inhalation

domestic water supply (e.g., water used for drinking, cooking, and bathing), agricultural use (e.g., livestock watering, irrigation), wildlife use, and industrial use. Relevant in-stream uses include swimming and other water contact sports, private and commercial fishing (resulting in ingestion of contaminated fish), and wildlife use. Sources for identifying withdrawal points and uses include the following:

- site vicinity surveys;
- state water agency records (including Clean Water Act "designated use" documentation for each surface water body);
- local water utility records;
- withdrawal permits; and
- EPA Office of Drinking Water data bases (e.g., Federal Reporting Data System).

Locate on a map the exact points of potential withdrawal and in-stream use in relation to the source from topographic maps.

At some sites, an important potential route of exposure via surface water is through the ingestion of contaminated fish or shellfish. Fish living in contaminated water can concentrate some contaminants from the water in their tissue. Due to the solubility of some contaminants in fats (e.g., PCBs), many chemicals are bioconcentrated and appear in the tissue at concentrations higher than in the surrounding water. Consumption of fish from surface water near sites may, therefore, be a significant potential human or wildlife exposure route.

Ground-Water Exposure. Determining points of current and future potential exposure to ground-water contaminants may require subsurface flow modeling. In general, nearby wells will have higher concentrations than distant wells, and downgradient wells will have higher concentrations than upgradient wells. Consideration must also include hydraulic connections between ground water and the identified surface water exposure points. Locations and depths of public water supply wells, domestic wells, agricultural wells, and industrial wells must be determined. In addition, any other relevant ground-water uses must be identified. Potential sources of well information include the following:

- site vicinity surveys;
- state or local agency well logs;
- EPA Office of Drinking Water; and
- U.S. Geological Survey (USGS).

If comprehensive ground-water modeling is planned, do not determine the significant exposure points until the modeling is completed. The modeling results can then be used to determine the significant exposure points (i.e., exposure points with high concentrations).

Soil Exposure. Areas of highest current and future direct exposure to contaminated surface soil will generally be on or directly adjacent to the site. If access to the site is not restricted, the site itself must be assumed to be the point of highest exposure to surface soil. If site access is limited (e.g., fencing and deed restrictions), the significant exposure point for soil often will be the nearest facility boundary, although wildlife, especially birds and flying insects, may still be exposed to high concentrations within the facility boundary.

Direct human exposure is from soil that is transferred to the mouth by the hands and wind. Wildlife also ingest and inhale soil particles. Dermal exposure may also be significant. A possible indirect route of exposure from soil contamination is chemical uptake by plants, with subsequent ingestion by humans or wildlife. As for the other exposure pathways, future potential exposure points (e.g., on site) and current potential exposure points (e.g., nearest residence) must be considered.

Air Exposure. For current and future potential air exposures, only systems containing highly volatile waste will generally be of concern. For aboveground or onground systems, secondary containment reduces direct air exposure risks by reducing the surface area of volatile waste exposed to air. For inground or underground systems, secondary containment reduces indirect air exposure risks by reducing contaminated ground water flowing or being pumped to the surface, infiltrating into basements, or being used for showering, bathing, etc.[5]

The individual or population potentially exposed to the highest direct air concentrations will generally be located downwind of and nearest to the source; however, this is not always the case. For example, the point of highest ambient ground-level concentration may be some distance from the source if the source is elevated. In these more complex situations, the appropriate exposure point must be determined in conjunction with air modeling efforts (as described in Section 5.2). The individual or population potentially exposed to the highest indirect air concentrations must be determined on a site-specific basis.

Once the future populations are determined, it is relatively straightforward to locate the closest existing population exposed to air releases. These populations can be located in residential, industrial, commercial, or undeveloped areas, or at other points of human activity. Potential sources of this information include the following:

- site vicinity surveys;
- topographic maps;
- aerial photographs of the site;
- county or city land-use maps; and
- census data.

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[5] Recent studies indicate that exposure of volatile chemicals due to showering in contaminated water may be greater than exposure from drinking the contaminated water. For a reference list and recent review, see the following: Foster, S.A. and Chrostowski, P.C., Integrated Household Exposure Model for Use of Tap Water Contaminated with Volatile Organic Chemicals, ICF-Clement Associates, Inc., Washington, DC, June 1986.

On a map, indicate precisely for each air release source the direction and distance to the significant exposure point. Again, one must determine future potential exposure points as well as current potential exposure points.

The point of highest direct short-term individual exposure by air may well be different from the point of highest long-term exposure. The highest direct short-term exposure point will generally be the closest potential population in any direction from the site, whereas the highest direct long-term exposure point will, in most cases, be downwind. Therefore, select the exposure point for determining long-term concentration within the downwind 90° arc from the emission source (45° on each side of the average downwind centerline as determined from historical wind data for locations near the site), unless it can be demonstrated that long-term concentrations will be higher elsewhere. These determinations often require site-specific data. In many cases, historical wind data for airports and other locations may be used. One source of this information is the National Oceanic and Atmospheric Administration (NOAA).

5.1.3 Integrate Release Sources, Transport Mechanisms and Media, and Exposure Points and Routes into Exposure Pathways

Examine the information developed in the previous two steps and determine the complete exposure pathways that exist for the site. Use Worksheet 5-1 to identify complete exposure pathways. A complete pathway is one that has all the necessary components: a source of chemical release, a transport mechanism, an environmental transport medium, a potential human or environmental receptor exposure point, and a likely route of exposure. For example, if there is no current ground-water use, then the current exposure pathway is incomplete. But, if the ground water is potable, then the future exposure pathway is complete. The exposure points for the complete exposure pathways define the spatial locations at which chemical concentrations must be projected. The health and environmental hazard evaluations developed in Chapters 6 and 7 are based on exposures at these locations.

In some cases, exposures via identified pathways may be non-quantifiable. There are a number of possible reasons for this, including the absence of adequate models on which to base estimates of chemical releases, environmental concentrations, or human intakes. If an exposure pathway is determined to be non-quantifiable during the exposure assessment procedure to follow, continue to include it as a potential pathway on all subsequent worksheets, designating it as non-quantified. This information can be taken into account in assessments of the uncertainty of the results.

5.1.4 Determine Presence of Sensitive Populations and Environmental Receptors

Review the information on the site area and identify any human populations or environmental receptors with high sensitivity to chemical exposure. Sensitive subpopulations that may be at higher risk include infants and children, elderly people, people with chronic illnesses, sensitive wildlife habitats, and endangered species. Generally, it must be assumed that these subpopulations are present, but any readily identifiable sensitive subpopulations should be noted.

To identify sensitive subpopulations on or near the facility, determine locations of schools, day care centers, hospitals, nursing homes, retirement communities, sensitive wildlife habitats, and endangered species that are potentially affected. Use local census data and information from local public health and wildlife officials for this determination. Record this information on Worksheets 5-1 and 5-2.

5.2 ESTIMATE EXPOSURE POINT CONCENTRATIONS

This section provides guidance on estimating exposure point concentrations of indicator chemicals.[6] At this point in the variance application, there are three possibilities concerning exposure pathways: (1) no current or future exposure pathways exist; (2) a current or future pathway exists; and (3) it has not been concluded whether a current or future exposure pathway exists. If current or future exposure pathways do not exist, then the demonstration of no substantial hazard to human health or the environment is essentially complete. If current or future exposure pathways do exist, then the concentration estimates obtained from the environmental fate and transport modeling described in this section will be used for characterizing risk (Chapters 6 and 7). If it has not been concluded whether a current or future exposure pathway exists, then the environmental fate and transport modeling described by this section will assist in that determination.

Estimating ambient concentrations at an exposure point is essentially a two-step process. The first step, quantifying the amounts of chemicals that will be released to the environment, was completed as described in Chapter 2. Given these release quantities, the second step is to predict the environmental transport and fate of each indicator chemical in the identified medium of the exposure pathway. An example is the movement of a contaminant released to ground water from contaminated soil and then transported to a drinking water well. For situations where prior releases have occurred, available ground-water monitoring data can be used to support estimates on the extent and duration of exposure. Concentrations associated with these prior released chemicals would be considered background concentrations.

Concentrations for each indicator and background chemical must be estimated at each of the complete exposure point locations identified in Worksheets 5-1 and 5-2. Concentrations of substances need to be estimated as a function of time (i.e., short-term and long-term) in each environmental medium (i.e., surface water, ground water, soil, or air) through which potential exposures could occur. For example, if in completing Worksheet 5-1, it is determined that potential exposure routes for a nearby residential area are ingestion of contaminated ground water and inhalation of contaminated air, chemical concentrations over time must be predicted for both ground water and air at this location.

Numerous analytical techniques are available to perform the calculations required in these two steps. The techniques are described in detail elsewhere (see footnote 2). The techniques vary in sophistication from simple, desk-top methods that provide rapid, order-of-magnitude projections, to more rigorous approaches involving computer modeling that may give more accurate results, but require more time and resources to undertake. All techniques require certain chemical- and site-specific data, although the data requirements vary with the degree of sophistication of the method used. The appropriate level of sophistication will be influenced by data availability, and by the demands and bounds of the evaluation for a specific site. Modeling, especially of long-term subsurface transport, has significant uncertainty associated with it that must be considered. Ground-water models have not been validated over the long time periods of concern, and many subsurface environments (e.g., anisotropic, heterogeneous) are not suited to available models. Sophisticated computer models are expensive to use, often require extensive data inputs, and still may have limited accuracy because of gaps in the input data. **Thus, simple environmental fate models using conservative (i.e., reasonable worst case) assumptions are usually most appropriate for use in risk-based variance applications.** If more complex models are used, reasonable worst case assumptions are usually still needed due to the uncertainties involved. In any case, the applicant must thoroughly document the models used and include validation references and documentation of previous applications.

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[6] Note that the list of indicator chemicals includes the background chemicals evaluated in Chapter 4.

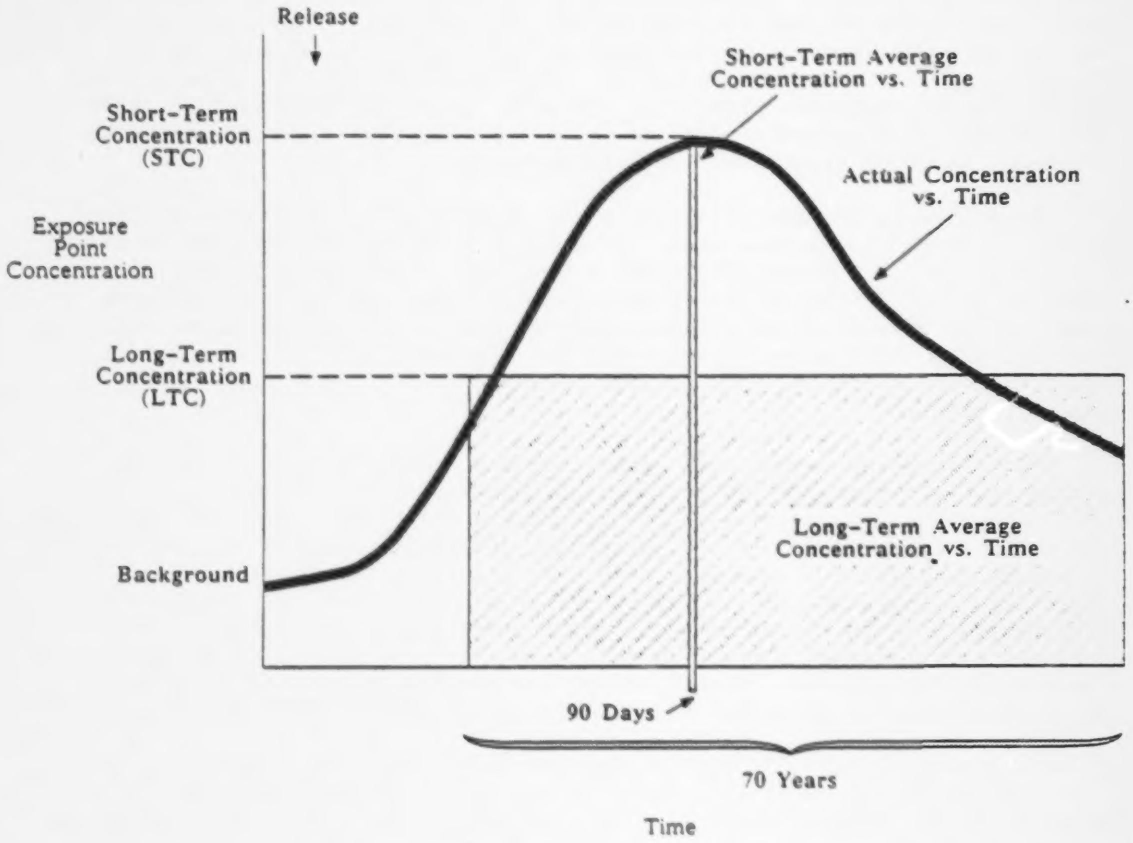
Ideally, the concentrations derived from modeling will be in the form of exposure profiles similar to the release profiles discussed in Chapter 2. Due to dispersion, degradation, and other factors, the exposure profile at any given exposure point will be attenuated compared to the release profile. That is, the peak concentration will not be as high as the concentration associated with the release volumes, and the length of time that the chemical will be present at the exposure point will be longer than the release duration. Exhibit 5-5 depicts an idealized curve of concentration versus time and, as shown, the concentration will generally increase over time to some maximum level and then decrease (assuming the release ends) to a background level. This background level may actually remain higher than the previous background level due to chemical- and media-specific properties (e.g., adsorption).

Short-term concentrations (STC) are averaged over a relatively short time period (10 to 90 days) and are used to evaluate potential subchronic effects of exposure for the human health effects evaluation and acute effects for the environmental impact evaluation. Long-term concentrations (LTC) are averaged over longer time periods, up to an average human lifetime (70 years) for the health effects evaluation and less for the environmental impact evaluation. LTCs are used to assess both the carcinogenic and chronic noncarcinogenic effects of exposure. For human exposure and environmental receptor exposure, the LTC will always be less than or equal to the STC.

Exhibit 5-5 illustrates the difference between STC and LTC. The STC may be viewed as the highest average concentration occurring during any group of consecutive days (generally 10 to 90). In Exhibit 5-5, the STC is essentially the peak concentration (since 10 to 90 days is a short time compared to the time frame of this particular curve). The LTC is somewhat more difficult to derive than the STC. In addition, different LTCs are often used to assess carcinogenic and chronic noncarcinogenic health risks. One method for assessment of carcinogenic human health risk is to estimate the area under the curve of exposure point concentration versus time, either graphically or mathematically, and divide by 70 years. This procedure is illustrated by the large shaded box in Exhibit 5-5. For assessment of chronic noncarcinogenic

Exhibit 5-5

ILLUSTRATION OF SHORT-TERM AND LONG-TERM CONCENTRATIONS*



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*Not to Scale

health risks, the LTC should sometimes be an average over a shorter time period than 70 years (thereby avoiding the artificial reduction of the LTC value resulting from averaging over a full lifetime). The averaging time for assessing long-term noncarcinogenic human health risk should correspond to that used in the toxicologic study from which the toxicity values (i.e., reference doses) were derived. Unless otherwise known, 10 years should be used for human exposure (corresponding to the 90-day subchronic studies from which many of the chronic toxicity values are derived). Therefore, the LTC to use for assessing chronic noncarcinogenic human health risk would be the highest 10-year average concentration. If significant noncarcinogenic human health risk is projected using this approach, it may be necessary to refer to the specific toxicologic studies on which the toxicity values are based to determine the most appropriate averaging period.

The following example illustrates the above points. The concentration from a catastrophic release might be high for a few months and then decrease substantially. The human STC would be obtained by averaging concentrations over the 10- to 90-day period of greatest exposure, the LTC for assessing human cancer risk would be the average over the 70-year period that results in the highest concentration, and the LTC for assessing human noncancer risk would be the average over the 10 year period that results in the highest concentration.

There are three recommended approaches for addressing the unavoidable estimation uncertainties likely to be encountered in the exposure assessment. One is to use a conservative (i.e., reasonable worst-case) approach in making the assumptions necessary for a particular estimation method. The consequence of making conservative assumptions is that risks may be substantially overstated but are unlikely to be understated in the final analysis. All assumptions and the basis for each should be recorded. This simple conservative approach is probably sufficient for the environmental impact evaluation, but is usually insufficient for the health effects evaluation because of the need to characterize uncertainty using a range of estimates.

A second and generally better approach is to calculate lower, representative, and upper estimates for all exposure point chemical concentrations. Ranges of constituent concentrations in the tank systems and ranges of hydrogeologic parameters are values that may be used to calculate lower, representative and upper exposure point concentrations. If this approach is followed and all three sets of concentration estimates are carried through the entire hazard evaluation (ultimately resulting in three sets of risk estimates), the results will provide not only an estimate of the risk magnitude but also a good indication of the overall uncertainty of the analysis. Of course, this approach requires more calculation effort, but it is a straightforward way to account for analytical and data uncertainties. This approach, which yields a lower, representative, and upper estimate of each risk projection, emphasizes the uncertainty involved by displaying it quantitatively. A large disparity between the estimates would indicate relatively high uncertainty, and vice-versa. This approach requires that three sets of worksheets be completed, one for the lower estimate, one for the representative estimate, and one for the upper estimate. The worksheets in this document are based on this approach.

A third possible approach, preferred, but **generally beyond the scope of the risk-based variance process**, is to model the important variables determining chemical concentration and risk stochastically. This approach is similar to the second in that a range of estimates is obtained. This stochastic approach differs from the first two deterministic approaches by allowing estimation of a risk distribution from which median and 90th (or other) percentile values can be determined. But this stochastic approach is more complex and time-consuming than a deterministic approach, and it still only accounts for uncertainty due to the variables modeled stochastically. It does not address other sources of uncertainty such as applicability of the release or transport models to the real site situation (i.e., model uncertainty).

To account for the behavior of all released chemicals, it is necessary to consider systematically the extent of chemical fate and transport in each environmental medium. In this way, one can consider the predominant mechanisms of chemical transport and transformation, and disregard less significant mechanisms. In the following sections, brief descriptions of the mechanisms for each of the major environmental release-media are presented. Worksheets 5-3 and 5-4 are provided as formats for recording the estimated chemical concentrations for each exposure point.

5.2.1 Surface Water Transport Modeling

The environmental fate of hazardous materials entering surface water bodies is highly dependent on the type of water body and the specific chemicals involved. Relatively simple, straightforward approaches are available for estimating environmental concentrations in rivers and streams. More complex methods, however, may be necessary for predicting concentrations resulting from releases to lakes, reservoirs, and estuaries. Applicable methods are described elsewhere (see footnote 2). In addition, states oftenhave approved models for use in issuing the National Pollutant Discharge Elimination System (NPDES) Permits as required by the Clean Water Act.

At some sites, relatively precise estimates of chemical fate and transport in surface water may be required. Sophisticated computer models are available for predicting the behavior of chemicals released to water. The models have varying capabilities, data requirements, computer resource requirements, and sophistication of output. The reasons for selecting a particular model should be well documented. Generally, for risk assessments in the risk-based variance application, the simplest model that reasonably represents the system should be used.

5.2.2 Ground-Water Transport Modeling

In describing the behavior of contaminants released to ground water from a hazardous waste tank system, two major subsurface zones must be considered: the unsaturated soil zone above the ground water (vadose zone), and the saturated zone, commonly called the aquifer. In general, after a substance is released, it first moves vertically down through the unsaturated soil zone to the ground water. Then, after initial mixing in the ground water, the substance travels horizontally because of the advective flow of the ground water underlying the site. The main processes that affect the fate and transport of contaminants in these two zones are advection (including infiltration and leaching from the surface), dispersion, sorption (including

WORKSHEET 5-3

CONTAMINANT CONCENTRATIONS AT HUMAN EXPOSURE POINTS

INSTRUCTIONS:

1. List all human indicator chemicals (use additional worksheets if necessary).
2. List all release media for each chemical: ground water, surface water, soil, and air.
3. List all exposure points for each release medium.
4. List projected short-term and long-term concentrations (lower, upper, and representative) for each exposure point. Be sure to include background concentrations from Worksheet 4-2. Note that water concentrations are in mg/l, air concentrations are in mg/m3, and fish concentrations are in mg/kg. Attach to this worksheet all calculations documenting the concentration estimates to this worksheet.

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Chemical	Release Medium	Exposure Point	Concentration Units	Short-Term Concentration Lower	Upper	Repres.	Long-Term Concentration Lower	Upper	Repres.
Benzene	Air	Nearest Residence	mg/m3	0.01	0.50	0.026	0.001	0.03	0.0040
	Ground water	Nearest Residence	mg/l	0.05	8.0	0.20	0.001	0.10	0.0085
Lead	Ground water	Nearest Residence	mg/l	0.02	2.0	0.045	0.001	0.03	0.0050

WORKSHEET 5-4

CONTAMINANT CONCENTRATIONS AT ENVIRONMENTAL RECEPTOR EXPOSURE POINTS

INSTRUCTIONS:

1. List all environmental indicator chemicals (use additional worksheets if necessary).
2. List all release media for each chemical.
3. List all environmental receptor exposure points for each release medium.
4. List projected short-term and long-term concentrations for each exposure point. Be sure to include background concentrations from Worksheet 4-2. Note that water concentrations are in mg/l and air concentratons are in mg/m3. Attach all calculations documenting the concentration estimates to this worksheet.

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Chemical	Release Medium	Exposure Point	Concentration Units	Short-Term Concentration	Long-Term Concentration
1. Benzene	Ground Water	Spring	mg/l	0.01	0.008
2. Lead	Ground Water	Spring	mg/l	0.005	0.001
3. Zinc	Ground Water	Spring	mg/l	0.001	0.0005
4.					

reversible adsorption, ion exchange, complexation, and precipitation), and degradation. As a released substance flows away from the source area, these processes generally act to reduce its concentration.

Time plays a key role in the movement of contaminants in the subsurface environment. Unlike the air (see below) and surface water media where releases of chemicals generally result in downwind or downstream ambient concentrations within relatively short times after release (i.e., minutes, hours, or days), ground water moves slowly and takes much longer (years) to transport contaminants. Consequently, the estimation of ground-water concentrations at a given exposure point must be bounded by a specified time frame for which the hazard evaluation will be conducted. Therefore, for purposes of evaluating long-term individual human health risks, ground-water concentrations estimated for the long-term time period with the highest average concentration should be used. To represent short-term concentrations, use the peak concentration value.

Numerous mathematical models are available that describe pollutant fate and transport in the subsurface environment. These models are described elsewhere (see footnote 2). These models attempt to define waste migration over time and distance using the physical and chemical processes involved. The physical and chemical characteristics considered by these models include the following:

- boundary conditions (hydraulic head distributions, recharge and discharge points, locations and types of boundaries);
- material properties (hydraulic conductivity, porosity, transmissivity, extent of hydrogeologic units);
- attenuation mechanisms (adsorption-desorption, ion exchange, complexing, nuclear decay, ion filtration, gas generation, precipitation-dissolution, biodegradation, chemical degradation);
- molecular diffusion and hydrodynamic dispersion (transverse, longitudinal, vertical, and multi-phase); and
- waste constituent concentrations (initial and background concentrations, boundary conditions).

These characteristics are incorporated into models by combining two sets of transport expressions: a ground-water flow equation and a chemical mass transport equation. The result is a prediction of solute transport in the ground-water system, with chemical reactions considered.

Separate models exist for predicting transport through both the unsaturated and saturated zones. Models are often linked into a comprehensive package to effectively simulate movement through both unsaturated and saturated soil zones. In addition, some ground-water models have the capability of predicting hazardous substance fate throughout both zones. Most of these models are designed to be used with a computer.

Models for ground-water transport generally have not been fully verified, and their reliability is difficult to assess. Site-specific conditions and the analyst's ability to account for site-specific characteristics with quantitative input data influence the reliability of model results. Carefully applied professional judgment is therefore necessary both in using the models and in interpreting the results. Important sources of uncertainty should be noted and their impact on model results should be anticipated and recorded.

5.2.3 Air Transport Modeling

The predominant mechanisms that affect the atmospheric fate and transport of substances released to the air are advection, dispersion and, in some cases, natural decay. Ambient concentrations of a chemical at a specified downwind distance from the site or in the ambient indoor air can be determined as a direct function of chemical release rate when these key processes are considered. See footnote 2 for guidance on appropriate modeling techniques .

Sophisticated computer models are also available for the analysis of environmental fate of hazardous substances in air. As with the models for other media, these models vary in complexity, input data requirements, computer resource requirements, and model capabilities. Again, simple models are generally preferable. If a computer modeling approach is desired for a particular situation, select the modeling procedure most appropriate to the circumstances under study. Again, document the rationale for selecting a particular model.

CHAPTER 6

HEALTH EFFECTS EVALUATION

The health effects evaluation is a major part of the demonstration for a risk-based variance from the secondary containment requirements of the hazardous waste tank system regulations. This chapter presents a method for compiling the information described in Chapters 2 through 5 for the purpose of evaluating the present and potential hazard to human health in the event of a release of hazardous waste from specific tank systems or components. The evaluation has two main components: (1) a comparison of estimated human exposure point concentrations (from Chapter 5) to health-related quality standards; and (2) a quantitative estimate of potential noncarcinogenic and carcinogenic risk. The first component of the health effects evaluation, comparison of exposure point concentrations to quality standards, is addressed in Section 6.1. In certain situations this comparison to standards will suffice for the health effects evaluation. The second component, quantitative estimates of risk, is addressed in Sections 6.2, 6.3, and 6.4. Section 6.2 provides a format for estimating chemical intake by humans at the exposure points, Section 6.3 guides the applicant in obtaining toxicity values of the chemicals, and Section 6.4 demonstrates the procedures for combining intakes with toxicity values to obtain estimates of human health risk. See Exhibit 6-1 for a flowchart of this process.

6.1 COMPARE EXPOSURE POINT CONCENTRATIONS TO ESTABLISHED QUALITY STANDARDS

At this point in the process, the projected concentrations of indicator chemicals at exposure points[1] are compared to established quality standards.[2] If the ratio of a projected concentration to an established quality standard for a particular chemical at an exposure point is greater than one, then adverse health effects may be anticipated. To consider possible cumulative effects, the ratios of projected concentration to established quality standard for each chemical are summed for each exposure media (i.e., water or air) at each exposure point. If this sum is greater than one, and if the standard is entirely health-based and chemicals involved produce the same adverse effect by similar modes of action, then adverse effects may be anticipated. Further guidance on the interpretation and calculation of the summation of ratios may be obtained from the Guidelines for the Health Risk Assessment of Chemical Mixtures (51 Federal Register 34014, September 24, 1986).

There are basically two types of quality standards: (1) those that are strictly health-based; and (2) those that, in addition to being health-based, also consider risk-benefit balancing or technological feasibility. If any standards exist for an indicator chemical, then the standards(s) must be

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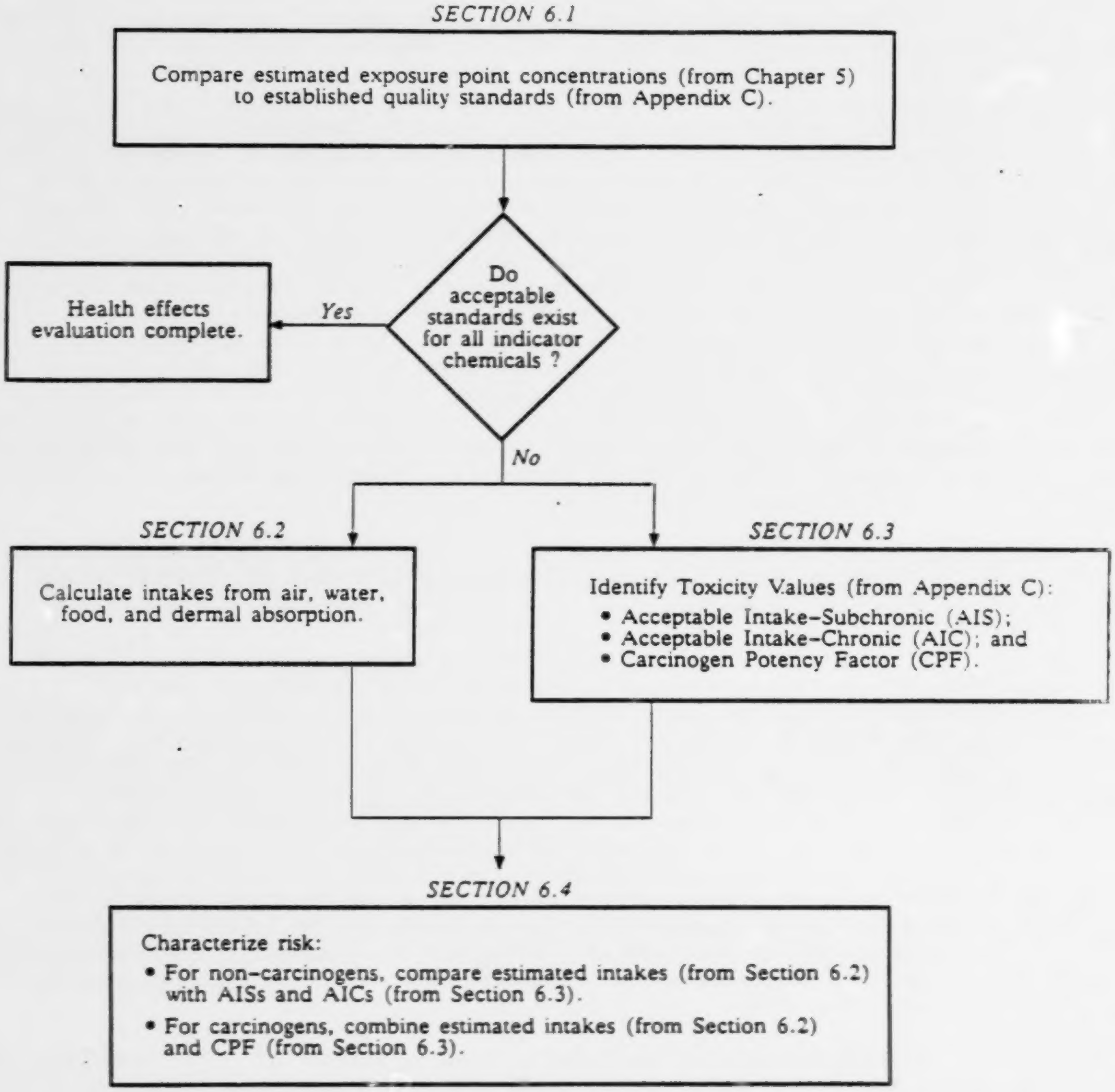
[1] Note that the list of indicator chemicals includes the background chemicals evaluated in Chapter 4.

[2] For the purpose of this discussion, "standard" refers to any health-based standard, criterion, goal, or advisory.

Exhibit 6-1

OVERVIEW OF HEALTH EFFECTS EVALUATION


SECTION 6.1
Compare estimated exposure point concentrations (from Chapter 5) to established quality standards (from Appendix C).
Do acceptable standards exist for all indicator chemicals ?
Yes
Health effects evaluation complete.
No
SECTION 6.2
Calculate intakes from air, water, food, and dermal absorption.
SECTION 6.3
Identify Toxicity Values (from Appendix C):
• Acceptable Intake-Subchronic (AIS);
• Acceptable Intake-Chronic (AIC); and
• Carcinogen Potency Factor (CPF).
SECTION 6.4
Characterize risk:
• For non-carcinogens, compare estimated intakes (from Section 6.2) with AISs and AICs (from Section 6.3).
• For carcinogens, combine estimated intakes (from Section 6.2) and CPF (from Section 6.3).

compared to the estimated exposure point concentrations. The standards that are most pertinent to site exposure conditions will be judged for acceptability. That is, the organism (tested or studied), the temporal aspect, any economic and/or technological considerations, and the environmental media and its use must all be reasonably identical to those of the exposure point. For example, standards that were established under statutory authority requiring risk-benefit balancing or technology-based considerations may not always be acceptable.[3]

This section describes the procedure for comparing exposure point concentrations to standards. Although the applicant should be aware that EPA continues to update toxicological information and, based on these updated data, may issue revised standards, the focus is on numerical criteria that are in the form of ambient environmental concentration levels. Standards expressed in intake or dose units are considered in the sections concerning quantitative estimates of risk (Sections 6.2, 6.3, and 6.4).

The comparison of exposure point concentrations to acceptable established standards for all indicator chemicals will usually suffice for a human health effects evaluation. Consequently, if all indicator chemicals in a tank system have acceptable standards, then the remainder of the risk assessment described in this chapter is not necessary. At sites where some indicator chemicals do not have acceptable standards, make the comparison for those chemicals that do have standards and then proceed with the complete risk characterization process for all indicator chemicals. Therefore, in cases where acceptable standards are not available for all indicator chemicals, the health effects evaluation will include both a comparison to standards and the risk assessment process described in the remainder of this chapter.

At the present time, EPA considers the established standards to be Safe Drinking Water Act maximum contaminant levels (MCLs), MCL goals (MCLGs), federally-approved state water quality standards[4] developed under the Clean Water Act, other state standards, federal ambient water quality criteria (WQC), and national ambient air quality standards (NAAQSs). Federal drinking water health advisories (DWHAs) are nonregulatory (i.e., nonenforceable) standards, although they are useful for comparison purposes in lieu of other standards. Appendix C lists all of the above standards and criteria for ambient environmental concentrations of contaminants.

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[3] 51 Federal Register 25453, July 14, 1986.

[4] States known to have specific numerical ambient water quality standards for toxic chemicals include Alabama, Alaska, Arizona, Arkansas, Delaware, Florida, Illinois, Indiana, Iowa, Kentucky, Louisiana, Minnesota, Mississippi, Montana, Nebraska, New Jersey, New Mexico, North Dakota, Ohio, Oregon, Pennsylvania, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, West Virginia, and Wisconsin. Appropriate state agencies for these and other states should be consulted to determine if such standards are in effect at the time of the site evaluation.

The determination of exactly which standards are acceptable to a particular site should be made on a site-specific basis. Not all standards will be acceptable for every site. For potential ground-water and surface water exposure via public drinking water, the most acceptable comparison values may be MCLs. For other surface water, when aquatic organism ingestion is an exposure pathway, unadjusted ambient water quality criteria may be most acceptable. For other potential ground-water exposures, acceptable comparison values may be adjusted (for drinking water only) ambient water quality criteria. For air exposure,[5] NAAQSs are acceptable. Other standards may be used for comparison as well, provided they correspond to the environmental medium for which they were designed and are appropriate to site conditions. Criteria inappropriate for a health effects evaluation of long-term chemical exposures include LD_{50} values (the dose of a chemical that results in 50 percent fatality in a population) and unadjusted occupational threshold limit values (TLVs; average concentrations of chemicals in air that should not be exceeded during an eight hour per day, 40 hour work week). Standards should correspond to the medium (i.e., water or air) for which they were developed and must be relevant to site conditions. If standards are available for all indicator chemicals, but are not acceptable given the site exposure conditions, a full risk characterization must be completed.

Some ambient concentration standards will be pertinent to specific site conditions, while others can be adjusted to make them useful. For example, if a standard applies to a different environmental medium or exposure route than one of concern at a site, it would usually not be appropriate to use the standard without adjustment. As an illustration of this situation, water quality criteria, which were developed for surface water, will need to be adjusted for application to ground water by deletion of the fish ingestion exposure component (as in Exhibit C-10). Concentration requirements and criteria may also be based on a different level, frequency, or duration of exposure than those found at a specific site.

For some chemicals, several different standards may be acceptable as comparison values. In this case, note the most appropriate comparison value. Appropriateness is determined in part by how pertinent the criterion is to exposure conditions at the site (e.g., exposed population characteristics, duration and timing of exposure, exposure pathways) and in part by how recently the value was developed. Some standards have been developed recently and may reflect new information compared to older values. Some standards may have been scrutinized more closely than others and may consequently have more scientific credibility. Other standards may be current and scientifically accepted but not pertinent to exposure routes at the site and, therefore, unsuitable. Consequently, the most appropriate comparison value is the most current, credible, and pertinent value available.

Use Worksheet 6-1 to compare established quality standards to environmental concentrations projected for human exposure points (from Worksheets 5-1 and 5-3). Calculate ratios between predicted concentrations

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[5] Secondary containment may appreciably decrease air exposure risk from tank systems containing highly volatile compounds.

WORKSHEET 6-1

COMPARISON OF HUMAN EXPOSURE POINT CONCENTRATIONS TO ESTABLISHED STANDARDS

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

INSTRUCTIONS:

1. Indicate exposure point and list all indicator chemicals (use additional worksheets if necessary).
2. Record each chemical's concentration range and representative value (from Worksheet 5-3).
3. Refer to Exhibits C-8 to C-12 and any existing state water quality standards to obtain the established standards. Record the value of the standard (include the risk, if known, in parentheses), its source (i.e., Maximum Contaminant Level (MCL), Clean Water Act State Standard (CWASS), Other State Standard (OSS), National Ambient Air Quality Standard (NAAQS), MCL Goal (MCLG), Water Quality Criteria (WQC), or Drinking Water Health Advisory (DWHA)), and any other pertinent information (e.g., whether a DWHA value refers to a one-day or ten-day exposure). Indicate the most appropriate standard with an asterisk.
4. Calculate the ratios of concentrations to standards.
5. Sum the ratios within a standard (e.g., add all the MCL ratios), and sum the most appropriate ratios (no more than one for each chemical). Summed ratios greater than one should not be intrepreted too strongly unless further analysis has segregated the chemicals and their standards by critical effect.

Exposure Point: Facility boundary, west.

Concentration (circle one): Short-term Long-term

	Chemical	Projected Exposure Point Concentration (mg/l)			Established Quality Standards		Ratio of Exposure Point Concentration to Standard		
		Lower	Upper	Repres.	Value (mg/l)	Source	Lower	Upper	Repres.
1.	Cadmium	0.001	0.1	0.08	0.01	MCL*	0.1	10	8
					0.01	WQC	0.1	10	8
					0.018	DWHA	0.06	5.6	4.4
2.	Ethyl benzene	0.5	2.0	1.0	-	MCL	-	-	-
					2.4	WQC*	0.21	0.83	0.42
					3.4	DWHA	0.15	0.59	0.29
3.									
					Totals:	MCL	0.1	10	8
						WQC	0.31	10.83	8.42
						DWHA	0.21	6.19	4.69
					Most appropriate:		0.31	10.83	8.42

*Most appropriate standard.

and standards, and designate whether concentrations exceed or fall below the standards. Indicate the most appropriate standard based on the criteria discussed previously in this section. When risk levels associated with these standards are known, they should also be recorded. Although individual ratios may be less than one (indicating adverse health effects due to that chemical are unlikely), summing the ratios may result in a value greater than one (indicating possible health effects). Therefore, sum the ratios for each chemical within a standard (e.g., add all the MCL ratios) to obtain an indication of cumulative effects. Also, sum the most appropriate ratios (one for each chemical) from the worksheet. The assumption of additivity reflected in the ratio summation procedure is applied most properly to chemicals that produce the same effect by the same mechanism. Therefore, summed ratios greater than one should not be interpreted too strongly unless further analysis has segregated the chemicals and their standards by critical effect.

Factors used in the development of the required standards listed in Appendix C are discussed briefly in the following subsections.

6.1.1 National Primary Drinking Water Standards/Maximum Contaminant Levels (MCLs)

Drinking water standards developed under the Safe Drinking Water Act are promulgated as maximum contaminant levels (MCLs). MCLs are currently available for 16 specific chemicals (10 inorganics and 6 organic pesticides), total trihalomethanes (covers four chemicals), certain radionuclides, and microorganisms. An MCL for a toxic chemical represents the allowable lifetime exposure to the contaminant for an adult weighing 70 kilograms who is assumed to ingest two liters of water per day. Total environmental exposure of a particular contaminant from various sources was considered by EPA in calculating specific MCLs. The amount of the substance to which the average person is likely to be exposed from all sources (e.g., air, food, water) was estimated, and then the fraction of the total intake resulting from drinking water ingestion was determined. Lifetime exposure limits were set at the lowest practical level to minimize the amount of contamination ingested from water, especially when exposure from other sources is large. The MCL calculation is adjusted by an exposure factor to reflect bodily absorption associated with water consumption.

In addition to health factors, an MCL is required by law to reflect the technological and economic feasibility of removing the contaminant from the water supply. The limit set must be feasible given the best available technology and treatment techniques. A safety factor is included in each of the standards to provide adequate protection for sensitive populations that may be at special risk, such as infants and children. Safety factors vary from chemical to chemical because of the different health effects associated with each.

Note that EPA recently proposed MCLs, which will be established standards when promulgated, for eight volatile organic chemicals (50 Federal Register 46902-46933, November 13, 1985). They are currently in the form of MCL goals (MCLGs) (See Section 6.1.2). Under the Safe Drinking Water Act Amendments of 1986 (P.L. 99-339), EPA is required to promulgate MCLs for 83 contaminants within three years. When promulgated, these MCLs will also become established standards. Exhibit C-8 lists the MCLs promulgated as of publication of this document.

6.1.2 MCL Goals (MCLGs)

EPA is now in the process of developing maximum contaminant level goals (MCLGs),[6] which are entirely health-based, to serve as guidance for establishing drinking water MCLs. EPA recently promulgated MCLGs for eight volatile organic chemicals (40 CFR 141.50 (50 Federal Register 46880-46901, November 13, 1985)) and proposed MCLGs for a larger group of synthetic organic chemicals, inorganic chemicals, and microorganisms (50 Federal Register 46936-47022, November 13, 1985). When these proposed MCLGs are promulgated, they will automatically become established standards. Exhibit C-9 lists the MCLGs promulgated as of publication of this document.

6.1.3 Federally-Approved State Water Quality Standards

Federally-approved state water quality standards developed under the Clean Water Act are established standards in that state. At a minimum, states listed in footnote 4 have promulgated at least some federally-approved water quality standards for specific toxic chemicals. The tank owner/operator is responsible for determining the availability of appropriate state water quality standards for the water resources surrounding a facility.

State water quality standards under the Clean Water Act serve the dual purposes of establishing the water quality goals for a specific water body and the regulatory basis for water quality-based controls beyond the technology-based levels of treatment required by Sections 301(b) and 306 of the Clean Water Act. Water quality standards are adopted by states (or, where necessary, promulgated by EPA) to protect public health and welfare, enhance the quality of the water, and serve the purposes of the Act. A water quality standard consists of basically two parts: (1) a "designated use" (or uses), based on the water body's use and value for public water supplies, propagation of fish, shellfish, wildlife, recreation, navigation, agriculture, industry, and other purposes; and (2) "criteria," which are numerical limits or narrative statements necessary to protect the designated use.

States must adopt appropriate water quality criteria sufficiently stringent to protect the designated uses. Numerical criteria may be based on ambient water quality criteria recommendations published by EPA (see Section 6.1.4) or developed by other scientifically defensible methods. States may also modify EPA's recommended criteria to reflect local environmental conditions and human exposure patterns before incorporation into water quality standards. When a criterion for the protection of human health must be developed for a chemical for which a national criterion has not been recommended, the state should consult EPA headquarters for assistance.[7]

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[6] MCLGs were previously known as recommended MCLs (RMCLs).

[7] Guidelines for deriving human health-based water quality criteria are published in 45 Federal Register 79318-79379, November 28, 1980.

6.1.4 Federal Ambient Water Quality Criteria (WQC)

Federal ambient water quality criteria (WQC) for the protection of human health have been developed for 62 out of 65 classes of toxic pollutants (a total of 95 individual chemicals have numerical health criteria). The health criterion is an estimate of the ambient surface water concentration that will not result in adverse health effects in humans. In the case of suspect or proven carcinogens, concentrations associated with an incremental cancer risk of 10^{-6} are provided to supplement a criterion of zero. The federal criteria are non-enforceable guidelines, which many states have used in the development of enforceable ambient water quality standards (see Section 6.1.3).

For most chemicals, federal WQC to protect human health have been published for two different exposure pathways. One criterion is based on lifetime ingestion of both drinking water and aquatic organisms, and the other is based on lifetime ingestion of aquatic organisms alone. The calculations incorporate the assumption that a 70-kilogram adult consumes 2 liters of water and/or 6.5 grams of aquatic organisms daily for a 70-year lifetime. Because the criteria based on lifetime ingestion of aquatic organisms alone are not relevant to most exposure situations, calculations have been made to derive an adjusted criterion for drinking water ingestion only, based on the two published criteria and the same intake assumptions. Exhibit C-10, therefore, presents the following: 1) the criteria based on lifetime ingestion of both drinking water and aquatic organisms; and 2) the adjusted criteria for drinking water only. The adjusted criteria are more appropriate than the non-adjusted for sites with potential contamination of ground-water sources of drinking water because they are based on more realistic exposure assumptions (i.e., exclusion of aquatic organism ingestion as an exposure pathway). WQC have been derived for both noncarcinogens and carcinogens. The following paragraphs briefly describe the methods used by EPA to derive WQC.

Derivation of Criteria for Noncarcinogens. On the basis of a survey of the toxicology literature, EPA established a "no observed adverse effect level" (NOAEL) for each chemical. The NOAELs are usually based on animal studies, although human data are used whenever available. By applying a safety factor to account for the uncertainty in using available data to estimate human effects, an acceptable daily intake (ADI) is determined. Criteria (i.e., water concentrations) are then derived from the ADIs and the standard intake assumptions given above.

Derivation of Criteria for Carcinogens. The same exposure and intake assumptions used for noncarcinogens are used for potential carcinogens. A literature search for human and animal carcinogenic effects form the basis for EPA's estimate of the risk posed by potential human carcinogens. Because methods are not currently available to establish the presence of a threshold for carcinogenic effects, the criteria for all carcinogens state that the recommended concentration for maximum protection of human health is zero. EPA also estimated water concentrations corresponding to incremental risk levels, using a linear, non-threshold extrapolation model. Extrapolation models provide only an estimate of risk, but represent the best available tool for describing the potential threat of a substance, given certain assumptions. In its published criteria, EPA provides water concentrations corresponding to incremental lifetime cancer risks of 10^{-7}, 10^{-6}, and 10^{-5}.

6.1.5 National Ambient Air Quality Standards (NAAQSs)

NAAQSs are available for six chemicals or chemical groups and for airborne particulates; of these, the NAAQSs for lead, hydrocarbons, and airborne particulates appear to be the most useful for the health effects evaluation. In the development of NAAQSs, sources of the contaminant that contribute to air pollution and all sources of exposure to the contaminant (e.g, food, water, air) are considered in determining the health risk. NAAQSs are based exclusively on air quality criteria (e.g., health effects, visibility) for each air pollutant and not the costs (economics) of achieving the standards or the technological feasibility of implementing the standards. Standards can be promulgated as annual maximums, annual geometric means, annual arithmetic means, or other time periods which vary from one hour to one year depending on the pollutant.

The standards must allow for an adequate margin of safety to account for unidentified hazards and effects. There is no rule used in setting the margin of safety for the standards. The law requires EPA to direct its efforts at groups of particularly sensitive citizens, such as bronchial asthmatics and emphysematics. In developing NAAQSs, EPA must specify the nature and severity of the health effects of each contaminant, characterize the sensitive population involved, determine probable adverse health effect levels in sensitive persons, and estimate the level below which an adequate margin of safety reduces or eliminates risks. NAAQSs are based primarily on the direct health effects of chemicals to sensitive groups based on scientific data. Exhibit C-12 lists the existing NAAQSs.

6.1.6 Drinking Water Health Advisories (DWHAs)

In addition to MCLs and MCLGs, EPA also provides drinking water suppliers with guidance on chemicals that may be encountered in a water system, but for which no federal standard exists. The Office of Drinking Water's nonregulatory (i.e., nonenforceable) DWHAs are concentrations of contaminants in drinking water at which adverse effects would not be anticipated to occur. Therefore, they are useful as an indication of potential hazard. A margin of safety is included to protect sensitive members of the population. The DWHA numbers are developed from data describing noncarcinogenic end-points of toxicity (e.g., neurological effects, kidney damage). They do not incorporate quantitatively any potential carcinogenic risk from such exposure. The Office of Drinking Water has recently developed DWHAs for 54 chemicals or chemicals groups, and these values are summarized in Exhibit C-11.

Under certain circumstances and when the appropriate toxicological data are available, DWHAs may be developed for one-day, ten-day, longer-term (several months to several years), and lifetime durations of exposure. One-day and ten-day DWHAs are calculated for a 10 kg child (a one-year old infant) assumed to drink one liter of water per day. Lifetime DWHAs are calculated for a 70 kg adult, assumed to drink two liters of water per day. Longer-term DWHAs are calculated for both a 10 kg child and a 70 kg adult. For chemicals that are known or probable human carcinogens according to the proposed Agency classification scheme, non-zero one-day, ten-day, and longer-term DWHAs may be derived, with attendant caveats. DWHAs for lifetime exposures are not recommended for this group of substances. For these potential carcinogens, drinking water concentrations associated with a projected excess lifetime cancer risk of 10^{-6} are provided. Comparison of these values to measured or predicted drinking water concentrations provide an indication of the magnitude of potential carcinogenic risk.

6.2 ESTIMATE CHEMICAL INTAKES

If acceptable, established quality standards exist for all indicator chemicals, then the health effects evaluation is complete and, therefore, there is no need to proceed with Sections 6.2, 6.3, and 6.4. If acceptable standards do not exist for all indicator chemicals then proceed with Sections 6.2, 6.3 and 6.4. In this section (Section 6.2), methods are presented for estimating human exposures using the environmental concentrations of substances that were estimated by the methods described in Chapter 5.

Human exposure is expressed in terms of intake, which is the amount of substance taken into the body per unit body weight per unit time.[a] Intakes are calculated separately for exposures to chemical contaminants in each environmental medium (air, ground water, surface water, and soil). Then, for each potntially exposed population, intakes for the same route of exposure are summed, resulting in a total oral exposure and total inhalation exposure. Dermal exposure, if determined to be important, should be estimated separately.

Because short-term (subchronic) exposures to relatively high concentrations of chemical contaminants can cause different toxic effects than those caused by long-term (chronic) exposures to lower concentrations, two intake levels are calculated for each chemical: (1) the subchronic daily intake (SDI); (2) and the chronic daily intake (CDI). These calculated intakes are based on short-term and long-term concentrations derived for each indicator chemical and any identified chemicals from other sources (i.e., background) using the procedures in the preceding chapter. All intakes are expressed in mg/kg/day.

The following subsections give standard methods to estimate human intakes through air, ground water, and surface water. If other exposure routes, such as dermal absorption and soil ingestion are important, contact the Exposure Assessment Group, Office of Research and Development, U.S. EPA, Washington, D.C. 20460, for additional guidance. Standard intake assumptions are given in Exhibit 6-2. If more accurate site-specific information is available, it can be used to give a better representation of risk at the site. See Exhibit 6-2 for an example of how to use the standard assumptions and how to make

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[a] The term "intake" (i.e., the amount of substance taken into the body) is used instead of dose (i.e., the amount of substance absorbed by the body) because the information required to estimate dose is often unavailable. To estimate dose, information indicating the amount of a chemical that may be absorbed (e.g., across lung or gastrointestinal tract lining or through the skin) and subsequently distributed to target organs or tissues would be needed. When absorption data are available they can be incorporated into the assessment. Because adequate absorption data for specific chemicals are relatively rare, they cannot be used consistently and are not included here.

EXHIBIT 6-2

STANDARD VALUES USED IN DAILY INTAKE CALCULATIONS a/

Parameter	Standard Value	Reference
Average body weight, adult	70 kg	EPA, 1980
Average body weight, child	10 kg	ICRP, 1975
Amount of water ingested daily, adult	2 liters	NAS, 1977
Amount of water ingested daily, child	1 liter	NAS, 1977
Amount of air breathed daily, adult	20 m^3	EPA, 1980
Amount of air breathed daily, child	5 m^3	FDA, 1970
Amount of freshwater fish consumed daily, adult	6.5 g	EPA, 1980

a/ Example 1: Applying the standard assumptions.

Human Intake Factor = 2 liters/day water consumption ÷ 70 kg body weight
= 0.029 liters/kg/day.

If contaminant concentration is 3 mg/liter in drinking water:

Human Intake Factor x 3 mg/liter = 0.086 mg/kg/day intake.

Example 2: Applying adjusted assumptions.

If site data indicate that the exposed population has a water consumption rate of 1.2 liters/day and an average weight of 60 kg:

Human Intake Factor = 1.2. liters/day ÷ 60 kg = 0.02 liters/kg/day.

If the contaminant concentration is 3 mg/liter in drinking water:

Human Intake Factor x 3 mg/liter = 0.06 mg/kg/day intake.

adjustments based on more accurate intake and body weight information for the potentially exposed population. For example, higher than average fish consumption may be important for some sites where surface water contamination is a possible problem. In addition, the standard intake values do not account for reduced intakes resulting from human activity patterns that reduce human contact with the contamination (i.e., it is assumed that exposure occurs 24 hours per day for the entire period that contamination is present). This conservative approach can be modified based on site-specific information to the contrary. For example, if an industrial area is an inhalation exposure point, it may be appropriate to adjust the standard intake factor by the fraction of a year spent at the exposure point.

6.2.1 Calculate Ground-Water Intakes

Human exposure to contaminated ground water can occur when contaminated wells are used as a drinking water source. The degree of exposure depends on the concentration of the contaminant in drinking water, the amount of water consumed per day, and the duration of exposure. The measured or predicted concentrations (short-term and long-term) of each contaminant in ground water at each exposure point are given in Worksheet 5-3. Insert these values into appropriate columns of Worksheets 6-2 and 6-3. Note that separate worksheets must be prepared for each ground-water exposure point. Using Exhibit 6-2 and/or other available information, calculate a standard human intake coefficient for use in determining drinking water exposures. The intake coefficient is calculated by dividing the average drinking water intake by the average body weight to give a value in l/kg/day. This coefficient is then inserted into Worksheets 6-2 and 6-3.

Using Worksheets 6-2 and 6-3, estimate subchronic and chronic drinking water intakes for each indicator chemical at all relevant ground-water exposure points. Include the duration of exposure.

6.2.2 Calculate Surface Water Intakes

For potential exposures to contaminated surface water, calculate intakes from ingestion of drinking water and ingestion of contaminated fish, as appropriate for the site being assessed.

Drinking Water. Human exposure to contaminated surface water can occur when the surface water is used as a drinking water source. The degree of exposure to contaminants present in drinking water derived from surface water depends on the same factors described for drinking water derived from ground water. Obtain the concentrations (short-term and long-term) of each chemical present in surface water at each exposure point from Worksheet 5-3. Insert these values into the appropriate columns of Worksheet 6-4 and 6-5. The standard human intake coefficient for drinking water is the same as that used for calculating ground-water intakes (l/kg/day). Using Worksheets 6-4 and 6-5, estimate subchronic and chronic drinking water intakes for each indicator chemical at all relevant surface water exposure points. Include the duration of exposure.

WORKSHEET 6-2

SUBCHRONIC GROUND-WATER INTAKES

INSTRUCTIONS:

1. Indicate exposure point and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Using Exhibit 6-2 and/or other available information, calculate a human intake factor by dividing ground-water intake per day by body weight (e.g., 2 l/day/70 kg = 0.029 l/kg/day).
3. List all indicator chemicals (use additional worksheets if necessary) and their short-term concentrations in ground water (from Worksheet 5-3).
4. Determine Subchronic Daily Intake (SDI) using the following formula: SDI = Human Intake Factor × Short-Term Concentration.

Facility ID: ____________
Cluster/Tank System: ____________
Date: ____________
Analyst: ____________
Quality Control: ____________

Exposure Point: Nearest residences' private wells

Population: 100

Duration of Exposure: 30 days

Human Intake Factor (l/kg/day): 2 l/day/70 kg = 0.029 l/kg/day

Chemical	Exposure Point Short-Term Concentration (mg/l)			Daily Intake (mg/kg/day)		
	Lower	Upper	Repres.	Lower	Upper	Repres.
1. Benzene	0.001	0.03	0.02	.00029	.0087	.0058
2. Lead	0	0	0	0	0	0
3.						
4.						
5.						

WORKSHEET 6-3

CHRONIC GROUND-WATER INTAKES

INSTRUCTIONS:

1. Indicate exposure point and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Using Exhibit 6-2 and/or other available information, calculate a human intake factor by dividing ground-water intake per day by body weight (e.g., 2 l/day /70 kg = 0.029 l/kg/day).
3. List all indicator chemicals (use additional worksheets if necessary) and their long-term concentrations in ground water (from Worksheet 5-3).
4. Determine Chronic Daily Intake (CDI) using the following formula: CDI = Human Intake Factor × Long-Term Concentration.

Facility ID: ______

Cluster/Tank System: ______

Date: ______

Analyst: ______

Quality Control: ______

Exposure Point: Nearest residences' private wells

Population: 100

Duration of Exposure: 50 years

Human Intake Factor (l/kg/day): 2 l/day/70 kg = 0.029 l/kg/day

Chemical	Exposure Point Long-Term Concentration (mg/l)			Daily Intake (mg/kg/day)		
	Lower	Upper	Repres.	Lower	Upper	Repres.
1. Benzene	0.0001	0.003	0.002	.000029	.00087	.00058
2. Lead	0	0	0	0	0	0
3.						
4.						
5.						

WORKSHEET 6-5

CHRONIC SURFACE WATER INTAKES

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

INSTRUCTIONS:

1. Indicate exposure point and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Using Exhibit 6-2 and/or other available information, calculate a human intake factor by dividing surface water intake per day by body weight (e.g., 2 l/day/70 kg = 0.029 l/kg/day).
3. List all indicator chemicals (use additional worksheets if necessary) and their long-term concentrations in surface water (from Worksheet 5-3).
4. Determine Chronic Daily Intake (CDI) using the following formula: CDI = Human Intake Factor × Long-Term Concentration.

Exposure Point: City residences

Population: 100

Duration of Exposure: 50 years

Human Intake Factor (l/kg/day): 2 l/day/70 kg = 0.029 l/kg/day

	Chemical	Exposure Point Long-Term Concentration (mg/l)			Daily Intake (mg/kg/day)		
		Lower	Upper	Repres.	Lower	Upper	Repres.
1.	Benzene	0.0001	0.003	0.002	.0000029	.000087	.000058
2.	Lead	0	0	0	0	0	0
3.							
4.							
5.							

WORKSHEET 6-4

SUBCHRONIC SURFACE WATER INTAKES

INSTRUCTIONS:

1. Indicate exposure point and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Using Exhibit 6-2 and/or other available information, calculate a human intake factor by dividing surface water intake per day by body weight (e.g., 2 l/day/70 kg = 0.029 l/kg/day).
3. List all indicator chemicals (use additional worksheets if necessary) and their short-term concentrations in surface water (from Worksheet 5-3).
4. Determine Subchronic Daily Intake (SDI) using the following formula: SDI = Human Intake Factor × Short-Term Concentration.

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Exposure Point: City residences

Population: 100

Duration of Exposure: 30 days

Human Intake Factor (l/kg/day): 2 l/day/70 kg = 0.029 l/kg/day

	Chemical	Exposure Point Short-Term Concentration (mg/l)			Daily Intake (mg/kg/day)		
		Lower	Upper	Repres.	Lower	Upper	Repres.
1.	Benzene	0.001	0.03	0.02	.000029	.00087	.00058
2.	Lead	0	0	0	0	0	0
3.							
4.							
5.							

Fish Consumption. Another potential route of exposure from contaminated surface water is through the ingestion of contaminated fish. The factors that determine human exposure from contaminated fish are the contaminant concentration in the fish, the amount of fish consumed, and the duration of exposure. The concentration of a contaminant in fish can be estimated by multiplying the estimated concentration of the contaminant in surface water by the fish bioconcentration factor for that chemical. Obtain surface water concentrations for each chemical at each exposure point from Worksheet 5-3. Insert the appropriate values into the appropriate columns of Worksheets 6-6 and 6-7. Standard human intake coefficients are calculated by dividing standard freshwater fish intake per day by the average adult body weight. Obtain the fish bioconcentration factor for each chemical from Appendix C or other sources. Using Worksheets 6-6 and 6-7, estimate subchronic and chronic daily intakes (kg fish/kg body weight/day) from contaminated fish for each indicator chemical at all relevant surface water exposure points. Include the duration of exposure (i.e., the averaging time used for the short- and long-term exposure point concentrations).

6.2.3 Calculate Air Intakes

As discussed in Chapter 5, significant air risks are only expected when the hazardous waste constituents are highly volatile. Therefore, the reduction in direct air risk that secondary containment provides will generally be relatively small compared to the reduction in ground water and surface water risks. Consequently, extensive assessment of direct air intakes is unlikely to be required at most sites. Some situations will exist, however, where direct air risk (e.g., from volatile chemicals on soils) and indirect air risk (e.g., from showering in water contaminated with volatile chemicals) may be substantial and, therefore, must be considered.

Human intake of contaminants present in the air is dependent on the contaminant concentration, the frequency and volume of inhalation, the duration of exposure, and, in the case of particulates, particle size. The measured or predicted air concentrations (short-term and long-term) of each contaminant at specific exposure points are given in Worksheet 5-3. Insert these values into the appropriate columns of Worksheets 6-8 and 6-9. Note that a separate worksheet must be prepared for each inhalation exposure point. Using Exhibit 6-2 and/or other available information, calculate a standard human intake coefficient for use in determining air exposures. This value takes into account the frequency (breathing rate), volume, and duration of inhalation intake as well as an average human body weight. The intake coefficient is calculated by dividing the average daily air intake by the average body weight to give a value in m^3/kg/day. Insert the calculated coefficient into Worksheets 6-8 and 6-9.

Using Worksheets 6-8 and 6-9, estimate subchronic and chronic air intakes for each indicator chemical at all relevant exposure points. Include the duration of exposure. Note that absorption of chemicals into the body is not accounted for by the intake estimates (or by the critical toxicity values described in the latter part of this chapter). Therefore, if chemical-specific absorption data are available, they can be used to refine the assessment as long as the procedures and values are clearly documented.

WORKSHEET 6-6

SUBCHRONIC FISH INTAKES

Facility ID:
Cluster/Tank System:
Date:
Analyst:
Quality Control:

INSTRUCTIONS:

1. Indicate exposure point and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Record the bioconcentration factor (BCF) for each chemical (from Appendix C).
3. Using Exhibit 6-2 and/or other available information, calculate a human intake factor by dividing fish intake per day by body weight (e.g., 6.5 gm/day/ 70 kg x 1E-3 kg/gm = 9.3E-5 kg/kg/day).
4. List all indicator chemicals (use additional worksheets if necessary) and their short-term concentrations in surface water (from Worksheet 5-3).
5. Determine Subchronic Daily Intake (SDI) using the following formula:
   SDI = Human Intake Factor × BCF × Short-Term Concentration.

Exposure Point: General population
Duration of Exposure: 30 days
Population: 60
Human Intake Factor (kg/kg/day): 6.5E-3 kg/day/70 kg = 9.3E-5 kg/kg/day

Chemical	BCF (l/kg)	Exposure Point Short-Term Concentration (mg/l) Lower	Upper	Repres.	Daily Intake (mg/kg/day) Lower	Upper	Repres.
1. Benzene	5.2	0.01	0.3	0.2	.0000048	.00015	.000097
2. Lead	49	0	0	0	0	0	0
3.							
4.							
5.							

6-19

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Population: 20

[illegible] (kg/kg/day): 6.5E-3 kg/day/70 kg = 9.3E-5 kg/kg/day

	Daily Intake (mg/kg/day)		
	Lower	Upper	Repres.
1. [illegible]	.00000048	.000015	.000097
2. [illegible]	0	0	0
3.			
4.			
5.			

WORKSHEET 6-8

SUBCHRONIC AIR INTAKES

INSTRUCTIONS:

1. Indicate exposure point and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Using Exhibit 6-2 and/or other available information, calculate a human intake factor by dividing air intake per day by body weight (e.g., 20 m3/day /70 kg = 0.29 m3/kg/day).
3. List all indicator chemicals (use additional worksheets if necessary) and their short-term concentrations in air (from Worksheet 5-3).
4. Determine Subchronic Daily Intake (SDI) using the following formula: SDI = Human Intake Factor x Short-Term Concentration.

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Exposure Point: Nearest residences

Population: 100

Duration of Exposure: 10 days

Human Intake Factor (m3/kg/day): 20 m3/day/70 kg = 0.29 m3/kg/day

	Chemical	Exposure Point Short-Term Concentration (mg/m3)			Daily Air Intake (mg/kg/day)		
		Lower	Upper	Repres.	Lower	Upper	Repres.
1.	Benzene	0.01	0.3	0.2	.0029	.087	.058
2.	Lead	0	0	0	0	0	0
3.							
4.							
5.							

WORKSHEET 6-9

CHRONIC AIR INTAKES

INSTRUCTIONS:

1. Indicate exposure point and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Using Exhibit 6-2 and/or other available information, calculate a human intake factor by dividing air intake per day by body weight (e.g., 20 m3/day /70 kg = 0.29 m3/kg/day).
3. List all indicator chemicals (use additional worksheets if necessary) and their long-term concentrations in air (from Worksheet 5-3).
4. Determine Chronic Daily Intake (CDI) using the following formula:
CDI = Human Intake Factor x Long-Term Concentration.

Facility ID: ______
Cluster/Tank System: ______
Date: ______
Analyst: ______
Quality Control: ______

Exposure Point: Nearest residences

Population: 100

Duration of Exposure: 50 years

Human Intake Factor (m3/kg/day): 20 m3/day/70 kg = 0.29 m3/kg/day

	Chemical	Exposure Point Long-Term Concentration (mg/m3)			Daily Intake (mg/kg/day)		
		Lower	Upper	Repres.	Lower	Upper	Repres.
1.	Benzene	0.0001	0.003	0.002	.000029	.00087	.00058
2.	Lead	0	0	0	0	0	0
3.							
4.							
5.							

6.2.4 Calculate Intakes From Other Exposure Pathways

There are a number of other potentially important exposure pathways that are more difficult to quantify than those just described. Nevertheless, the human chemical intakes received through such pathways may be extremely important to certain populations at risk. For example, exposure may be by dermal absorption or direct ingestion of soil that has been contaminated by surface runoff.[9] Another potential exposure pathway could be agricultural land being irrigated with contaminated surface or ground water; human exposure would occur if produce is contaminated and ingested. Humans may also be exposed via consumption of game animals that reside in contaminated areas. Contaminated surface waters, in addition to providing drinking water, may be used for recreation and, therefore, humans may be exposed by swimming in such waters. This use may result in dermal, oral, and inhalation exposures. During bathing or showering, dermal or inhalation exposure may occur.[10] Volatilization while washing dishes or cooking with contaminated water may result in oral and inhalation exposure. If these additional intakes were not addressed in previous sections, they should be addressed here.

Formulas for these less common exposure pathways have not been included in this manual because there has been little experience on which to base standard formulas. It should be noted, however, that at certain sites and for certain populations at risk, these less common routes of exposure may be significant. Therefore, Worksheets 6-10 and 6-11 have been provided to allow calculation of these other intakes (e.g., inhalation while showering, exposure to soil, dermal exposure or surface water ingestion while swimming). If one of these exposure pathways has been identified as significant, then, for guidance on a method for calculating chemical intakes, contact the Exposure Assessment Group, Office of Research and Development, U.S. EPA, 401 M Street, S.W., Washington, D.C. 20460.

6.2.5 Combine Pathway-Specific Intakes to Yield Total Oral and Total Inhalation Intakes

In this step, total exposure scenarios are developed for each exposure point, and the relevant route-specific intakes are combined for the affected

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[9] This route of exposure is especially important for children playing outdoors. If young children will have access to an area with contaminated surface soil, exposure for this subpopulation via soil ingestion can be estimated based on the following assumptions: (1) ingestion is primarily of concern for children between age two and six; (2) ingestion rate varies from 0.1 to 5 grams per day, with higher values representative of pica behavior; and (3) body weight of children in this age group averages 17 kg, and ranges from 10 to 25 kg. These assumptions are based on U.S. EPA (1984), Kimbrough, et al. (1984), and Anderson, et al. (1984).

[10] Recent studies indicate that intake of volatile chemicals due to showering in contaminated water may be greater than intake from drinking the contaminated water. For a reference list and recent review, see the following: Foster, S.A. and Chrostowski, P.C., Integrated Household Exposure Model for Use of Tap Water Contaminated with Volatile Organic Chemicals, ICF-Clement Associates, Inc., Washington, D.C., June 1986.

WORKSHEET 6-10

OTHER SUBCHRONIC INTAKES

INSTRUCTIONS:

1. Indicate exposure point, type of intake, and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Using Exhibit 6-2 and/or other available information, calculate a human intake factor.
3. List all indicator chemicals (use additional worksheets if necessary) and their short-term concentrations (from Worksheet 5-3).
4. Determine Subchronic Daily Intake (SDI) using the following formula: SDI = Human Intake Factor × Short-Term Concentration.

Facility ID: ______
Cluster/Tank System: ______
Date: ______
Analyst: ______
Quality Control: ______

Exposure Point: Nearest residences
Population: 100
Intake: Soil inhalation
Duration of Exposure: 30 days
Human Intake Factor: 20 m3/day/70 kg = 0.29 m3/kg/day

	Chemical	Exposure Point Short-Term Concentration*			Daily Intake (mg/kg/day)		
		Lower	Upper	Repres.	Lower	Upper	Repres.
1.	Benzene	0.001	0.03	0.02	.00029	.0087	.0058
2.	Lead	0	0	0	0	0	0
3.							
4.							
5.							

* Air concentrations, in mg/m3.

WORKSHEET 6-11

OTHER CHRONIC INTAKES

INSTRUCTIONS:

1. Indicate exposure point, type of intake, and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Using Exhibit 6-2 and/or other available information, calculate a human intake factor.
3. List all indicator chemicals (use additional worksheets if necessary) and their long-term concentrations (from Worksheet 5-3).
4. Determine Chronic Daily Intake (CDI) using the following formula: CDI = Human Intake Factor × Long-Term Concentration.

Facility ID: ______
Cluster/Tank System: ______
Date: ______
Analyst: ______
Quality Control: ______

Exposure Point: Nearest residences
Population: 100
Intake: Soil inhalation
Duration of Exposure: 50 years
Human Intake Factor: 20 m3/day/70 kg = 0.29 m3/kg/day

	Chemical	Exposure Point Long-Term Concentration			Daily Intake (mg/kg/day)		
		Lower	Upper	Repres.	Lower	Upper	Repres.
1.	Benzene	0.0001	0.003	0.002	.000029	.00087	.00058
2.	Lead	0	0	0	0	0	0
3.							
4.							
5.							

* Air concentrations, in mg/m3.

population. This exposure summation gives the total daily oral intake and total daily inhalation intake of each chemical to which the population may be exposed.

In Chapter 5, chemical concentrations at the significant exposure points were estimated for each identified exposure pathway (see Worksheets 5-1 and 5-3). Recall that the significant exposure point for a pathway is the point of highest individual exposure, although locations with large exposed populations and lower exposure levels should also be included in the analysis as supplementary exposure points. Now the task is to determine, for each significant exposure point identified in Chapter 5, which of the other exposure pathways could contribute to total exposure at that point. Use Worksheet 6-12 to record this information. Be sure to list any potentially important non-quantified exposure pathways on Worksheet 6-12. If the populations at risk for different exposure pathways are mutually exclusive, do not sum intakes from both pathways for the same exposure point. For example, it is incorrect to sum the intakes associated with ingesting drinking water from different sources if each person's exposure is exclusively from one of the sources.

After a total exposure scenario has been developed for each significant exposure point (e.g., a population living near the site with private drinking water), combine the individual chemical intakes calculated for each of the oral exposure pathways identified for that exposure point. Do the same for inhalation. Referring to Worksheet 6-12, insert the appropriate intakes to be combined (from Worksheets 6-2 through 6-11) into Worksheet 6-13 (SDIs) and Worksheet 6-14 (CDIs). Note that some intake values from Worksheets 6-2 through 6-11 may need to be adjusted when applied to exposure points other than those specified. In situations where the significant exposure points of two pathways are relatively far apart, one must judge whether the additional calculation effort is warranted or whether simply summing the intakes for the significant exposure points is sufficient. For example, if the significant exposure points for an air and a ground-water pathway differ, one may choose either to adjust the intakes from Worksheets 6-2, 6-3, 6-8, and 6-9 before using them for a total exposure estimate or combine the unadjusted intakes for a conservative total exposure estimate.

The next step in the summation procedure is to add the intakes from drinking water, fish, and other oral ingestion for each chemical to give the total oral SDI (Worksheet 6-13) and CDI (Worksheet 6-14) for the population at risk at each significant exposure point. The existence of any non-quantified exposure pathways should be noted on these summary intake worksheets. In addition, be sure to note the number of people exposed at each significant exposure point.

The intake summation procedure described here is most relevant to the estimation of total chronic exposure levels. When estimating total subchronic exposures, be sure not to sum peak intake values estimated for different time periods for the same release. Remember, the time period defined as short-term is anywhere from a 10 to a 90 day period. If the SDI for one pathway is estimated to occur immediately and the SDI for another pathway affecting the same exposure point from the same release is predicted to occur in 5 years, it would be improper to sum these (they would affect the same population, but at

WORKSHEET 6-12

PATHWAYS CONTRIBUTING TO TOTAL EXPOSURE

INSTRUCTIONS:

1. List the exposure points for all exposure pathways being evaluated (from Worksheet 5-1) (use additional worksheets if necessary).
2. Determine the exposure pathways contributing to total exposure for each listed exposure point.
3. Note in the comments column which exposure pathways are only short-term, which are non-quantified, and any other pertinent information.

Facility ID: ___________

Cluster/Tank System: ___________

Date: ___________

Analyst: ___________

Quality Control: ___________

	Exposure Point	Exposure Pathways Contributing to Total Exposure	Comments
1.	Nearest downgradient	Ground-water ingestion	
	facility boundary	Soil contact	Non-quantified
		Air inhalation	
2.	Residences 1 mile SW on	Ground-water ingestion	
	vulnerable public wells	Air inhalation	Low exposure
3.	Hospital at 2 miles on	Ground-water ingestion	
	public well (sensitive)		

WORKSHEET 6-13

TOTAL SUBCHRONIC DAILY INTAKE (SDI)

INSTRUCTIONS:

1. Indicate exposure point, number of people, and whether intake estimates are lower, representative, or upper values (complete a separate worksheet for each type of estimate).
2. List all indicator chemicals (use additional worksheets if necessary).
3. Refer to Worksheet 6-12 and determine which exposure pathways are relevant for the exposure point.
4. Record SDIs (in mg/kg/day) for the exposure point from Worksheets 6-2, 6-4, 6-6, 6-8, and 6-10 in the appropriate columns.
5. Determine total SDI by adding the component SDIs for each chemical. For example, ground-water, surface water, and fish intakes would sum together for total oral SDI.

Facility ID: ______

Cluster/Tank System: ______

Date: ______

Analyst: ______

Quality Control: ______

Exposure Point: Nearest residences on private wells

Population: 100

Intake Estimates (circle one): Lower Upper Representative

	Chemical	Ground Water SDI	Surface Water SDI	Fish Ingestion SDI	Other Oral SDI	Total Oral SDI	Air SDI	Other Inhalation SDI	Total Inhalation SDI
1.	Benzene	0.0058	-	.000047	-	0.0058	-	-	0
2.	Lead	0.0013	-	.0000038	-	0.0013	-	-	0
3.									
4.									
5.									

WORKSHEET 6-14

TOTAL CHRONIC DAILY INTAKE (CDI)

INSTRUCTIONS:

1. Indicate exposure point, number of people, and whether intake estimates are lower, representative, or upper values (complete a separate worksheet for each type of estimate).
2. List all indicator chemicals (use additional worksheets if necessary).
3. Refer to Worksheet 6-12 and determine which exposure pathways are relevant for the exposure point.
4. Record CDIs (in mg/kg/day) for the exposure point from Worksheets 6-3, 6-5, 6-7, 6-9, and 6-11 in the appropriate columns.
5. Determine total CDI by adding the component CDIs for each chemical. For example, ground-water, surface water, and fish intakes would sum together for total oral CDI.

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Exposure Point: Nearest residences on private wells

Population: 100

Intake Estimates (circle one): Lower Upper Representative

	Chemical	Ground Water CDI	Surface Water CDI	Fish Ingestion CDI	Other Oral CDI	Total Oral CDI	Air CDI	Other Inhalation CDI	Total Inhalation CDI
1.	Benzene	0.0008	-	.00000017	-	0.0008	-	-	0
2.	Lead	0.0009	-	.00000018	-	0.0009	-	-	0
3.									
4.									
5.									

different times). In this situation, assessing short-term risks based on the higher of the two values usually will provide a reasonable assessment of short-term risks. Alternatively, if releases can occur from the same or different systems and result in SDIs from two different (or the same) pathways at the same time, then the total exposure would be the summation of these individual SDIs.

6.3 DETERMINE CHEMICAL TOXICITIES

The determination of whether or not a chemical poses a hazard to humans is crucial to the evaluation of the chemical's possible health effects. Information on toxicity must be used in conjunction with data on estimated intakes to characterize risk. Critical toxicity values for many common toxic substances, as documented in the Superfund Public Health Evaluation Manual, are presented in Appendix C of this guidance. Toxicity information for specific chemicals not listed in Appendix C is available through the Environmental Criteria and Assessment Office (ECAO), U.S. EPA, 26 W. St. Clair Street, Cincinnati, Ohio 45268. In some cases, it may be necessary to derive appropriate values based on available toxicological or epidemiologic data.

Three values that describe the degree of toxicity posed by a chemical are required in the evaluation of possible health effects:

- the acceptable intake for subchronic exposure (AIS)[11];
- the acceptable intake for chronic exposure (AIC)[11]; and
- the carcinogenic potency factor (for potential carcinogenic effects only).

These values are based on empirical data and have not been adjusted for site-specific conditions. In some cases, separate critical toxicity values will be available for ingestion and inhalation routes of exposure. These values are provided in Appendix C for many chemicals.

AIS and AIC values are required for all chemicals being evaluated. These values are derived from quantitative information available from studies of animals (or observations made in human epidemiologic studies) that examine the relationship between intake and non-carcinogenic toxic effects. They are designed to be protective of sensitive populations. For example, for teratogenic chemicals, AIS values are generally derived for the teratogenic effects.

If a chemical has a verified reference dose (RfD), that value should be used as the AIC.[12] Verified RfDs are for noncarcinogenic effects and are similar in concept to acceptable daily intakes (ADIs). In general, RfDs are based on the most sensitive effect resulting from chronic exposure. RfDs are being verified by an EPA Work Group chaired by the Office of Research and Development, in a process begun in 1985; they currently are available for approximately 100 chemicals.

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[11] The terms "AIC" and "AIS" are defined here only for the purposes of this evaluation.

[12] For chemicals without EPA-verified RfD values, AIC values may be developed from other sources, such as EPA's Health Effects Assessment documents.

AIS values are determined by a process similar to that used to develop RfDs, except that subchronic studies are the basis of the values instead of chronic studies. Most AIS values are based on subchronic animal studies (10 to 90 days), although some are derived from human exposure data. For chemicals without appropriate human data, the highest subchronic exposure level not causing adverse effects, or the "no observed adverse effect level" (NOAEL), is determined from all of the animal studies available in the literature. The NOAEL is then divided by appropriate uncertainty factors to derive the AIS. Uncertainty factors usually include a factor of ten to account for extrapolation from animal experiments to human effects and a factor of ten for intraspecies variability (i.e., to account for the fact that two individuals of the same species may not react to the same quantity of a chemical with the same level of response).

AIC values are usually based on long-term animal studies. Adequate human data are available for a few chemicals, and these data are used whenever possible. Literature values from all appropriate studies are used to determine the highest chronic exposure level that does not cause an adverse effect (NOAEL). As for the AIS determination, the NOAEL is divided by ten to extrapolate from animal effects to human effects, and is divided by ten to account for intraspecies variability. If sufficient data cannot be obtained on chronic effects, subchronic NOAELs are used and divided by an additional factor of ten to account for uncertainties caused by extrapolation from subchronic to chronic effects.

The carcinogenic potency factor is an estimated upper 95 percent confidence limit of the carcinogenic potency of the chemical. It is expressed as the lifetime cancer risk corresponding to one milligram of chemical intake per day per kilogram of body weight (mg/kg body weight/day) and it can be used at low doses to estimate an upper bound of cancer risk for a chemical.

Generally only a limited amount of new work will be necessary to determine chemical toxicities, as the assessment has already been done for many toxic chemicals. Thus, for most cases, it is only necessary to summarize toxicity data already available. If EPA has completed verification of an RfD for a specific chemical, it should be used as the AIC. If toxicity values are not available in Appendix C, contact ECAO for guidance. Use Worksheet 6-15 to summarize available data.

Three kinds of toxicity information should now have been gathered on each chemical of concern. These are subchronic and chronic acceptable intakes for noncarcinogenic effects, and carcinogenic potency factors for potential carcinogenic effects. The information that has been gathered on toxicity can be combined with data on estimated intakes to characterize long-term and short-term health risks. The procedure for doing this characterization is described in the next section.

WORKSHEET 6-15

CRITICAL TOXICITY VALUES

INSTRUCTIONS:

1. List all components of the waste or indicator chemicals (use additional worksheets if necessary).
2. List subchronic acceptable intake (AIS), chronic acceptable intake (AIC), and carcinogenic potency factor values (including carcinogenicity weight-of-evidence ratings).
3. For teratogenic chemicals (indicated in Appendix C), list a separate AIS for that effect only.

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Chemical	AIS (mg/kg/day)	AIC (mg/kg/day)	Carcinogenic Potency Factor (kg-day/mg)
Inhalation Route:			
1. Benzene	--	--	0.026(A) a/
2. Lead	--	0.00043	NA
3. Methyl ethyl ketone	2.2	0.22	NA
Ingestion Route:			
1. Benzene	--	--	0.052(A) a/
2. Lead	--	0.0014	NA
3. Methyl ethyl ketone	--	0.050	NA

a/ EPA weight-of-evidence rating in parentheses for potential carcinogens (provided in Appendix C).

NA = not applicable.

6.4 RISK CHARACTERIZATION

This step involves a comparison for noncarcinogens between the projected intakes determined in Section 6.2 and the acceptable intakes calculated in Section 6.3. For carcinogens, projected intakes from Section 6.2 are converted to carcinogenic risks and compared with a target risk for total exposure to carcinogens. The methodology for making each of these comparisons is different, so these two classes of toxicity are discussed separately in the remainder of this section. Exposure point concentrations have already been compared to established quality standards in Section 6.1 for those chemicals that have such standards; these comparisons will be combined with the risk characterization results in the overall health effects evaluation.

6.4.1 Noncarcinogenic effects

The overall process for evaluating noncarcinogenic effects is illustrated in Exhibit 6-3. If the hazardous waste tank for which the application is being submitted contains only one constituent of concern, the comparison between projected intake and acceptable intake is straightforward. If the projected intake is lower than the acceptable intake, no adverse health effects will be expected. If the projected intake exceeds the acceptable intake, adverse health effects may be anticipated.

In most cases, hazardous waste tanks will contain a number of constituents of concern. If this number is large, the applicant may have selected indicator chemicals to represent the wastes as described in Section 2.2 and these indicator chemicals should be evaluated here. **If the intake of any constituent is greater than its acceptable intake for subchronic exposure (AIS) or acceptable intake for chronic exposure (AIC), then an adverse health effect is likely.** If this is not the case, then the ratios of daily intake to acceptable intake (one for each chemical) summed for each pathway of exposure (e.g., oral, inhalation) at each exposure point. This procedure should be followed for both chronic and subchronic exposures.

As a first approach to risk characterization for several noncarcinogenic chemicals and effects, the assumption should be made that subthreshold exposures to the chemicals are additive and in total may cause an adverse effect. This approach reflects the Hazard Index approach presented in the Guidelines for the Health Risk Assessment of Chemical Mixtures (51 Federal Register 34014-34025, September 24, 1986). Hazard Indices are evaluated for each exposure point and are calculated as follows:

Subchronic Hazard Index[13] $= \frac{SDI_1}{AIS_1} + \frac{SDI_2}{AIS_2} + \ldots.. + \frac{SDI_i}{AIS_i}$

where SDI_i = subchronic daily intake calculated for the ith toxicant at an exposure point, and

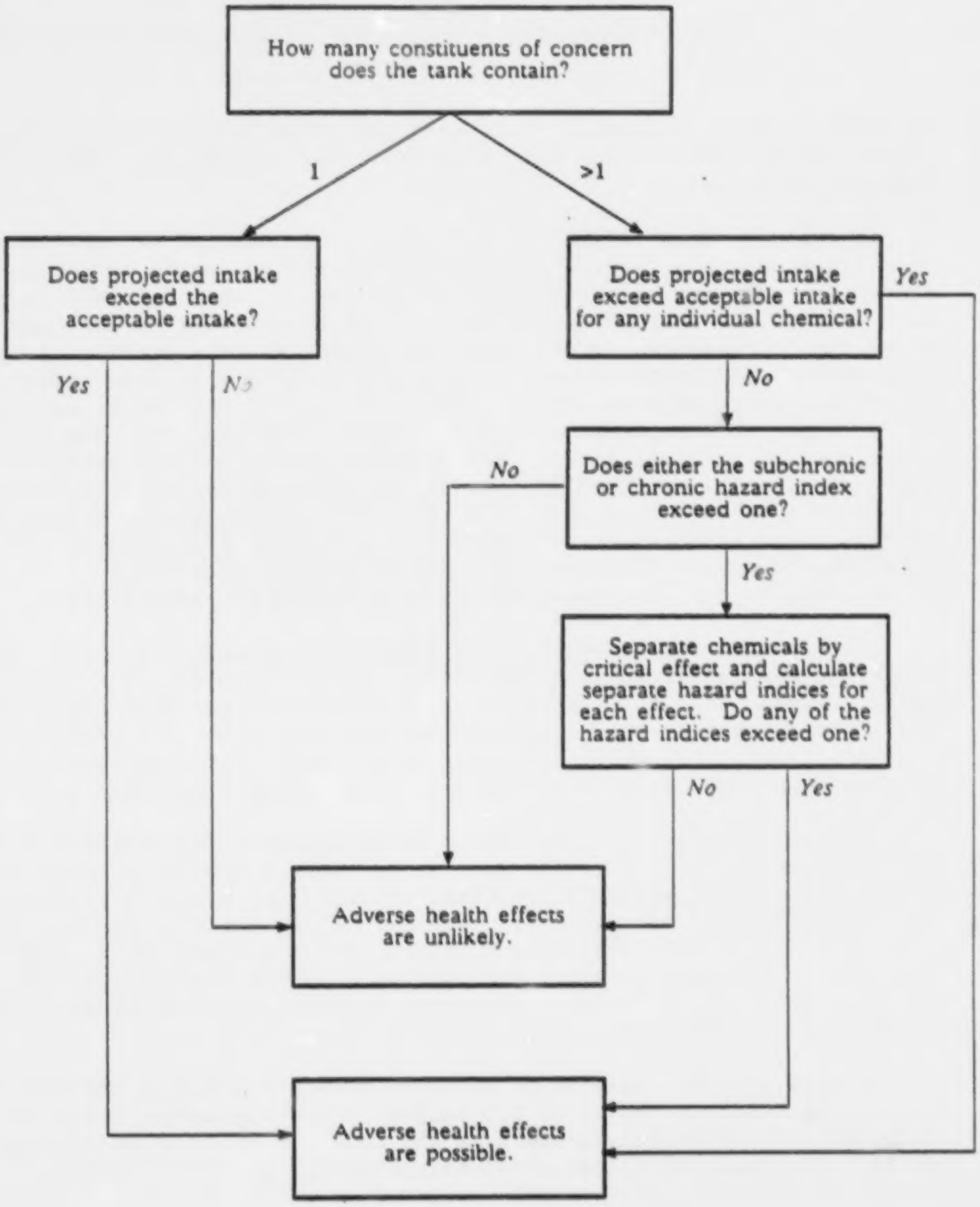
AIS_i = acceptable intake for subchronic exposure to the ith toxicant at an exposure point; and

---

[13] Ratios should be summed only for chemicals and exposure pathways for which the short-term concentration time period is the same.

Exhibit 6-3

DECISION TREE FOR THE EVALUATION OF POTENTIAL NONCARCINOGENIC EFFECTS


How many constituents of concern does the tank contain?
1
>1
Does projected intake exceed the acceptable intake?
Yes
No
Does projected intake exceed acceptable intake for any individual chemical?
Yes
No
Does either the subchronic or chronic hazard index exceed one?
No
Yes
Separate chemicals by critical effect and calculate separate hazard indices for each effect. Do any of the hazard indices exceed one?
No
Yes
Adverse health effects are unlikely.
Adverse health effects are possible.

$$\text{Chronic Hazard Index} = \frac{CDI_1}{AIC_1} + \frac{CDI_2}{AIC_2} + \ldots\ldots + \frac{CDI_i}{AIC_i}$$

where CDI_i = chronic daily intake calculated for the ith toxicant at an exposure point, and

AIC_i = acceptable intake for chronic exposure to the ith toxicant at an exposure point.

If either hazard index does not exceed one, then adverse health effects will likely not be experienced, but if either index exceeds one, then further analysis is necessary.

If the projected intake for any individual chemical of concern is greater than its acceptable intake, adverse health effects may be anticipated. The assumption of additivity reflected in the hazard index equation is applied most properly to [illegible]micals that produce the same effect by the same mechanism. There[illegible] if the equation is applied to a mixture of chemicals that produce dif[illegible]dverse effects, it is likely to overestimate the potential for an [illegible] effect. Consequently, if the sum of the ratios of daily intake to acc[illegible]e intake is greater than one, the chemicals should be segregated by critical effect, and separate hazard indices should be derived for each effect. Critical effects can be found in Health Effects Assessment Documents available from ECAO, U.S. EPA, Cincinnati, Ohio. A list of chemicals for which these documents are available as of October 1986 can be found in Appendix C, Exhibit C-7. Use Worksheets 6-16 and 6-17 to calculate hazard indices for subchronic and chronic exposures, respectively.

Intakes and risks from oral and inhalation exposure pathways should be estimated separately so that route-specific toxicity data in Appendix C can be used. However, the possible effects of multimedia exposure should be evaluated by summing the hazard indices for inhalation and oral exposures at each exposure point. This procedure will ensure that acceptable levels are not being exceeded by combined intakes when multiple exposure pathways exist.

It is emphasized that the hazard index is not a mathematical prediction of incidence or severity of effects. It is simply a numerical index to help identify potential exposure problems. Results for multiple chemicals should not be interpreted too strongly. A hazard index greater than one for multiple chemicals and effects indicates a potential for concern rather than a definite problem. Although a hazard index greater than one for multiple chemicals with the same effect is more indicative of a problem, uncertainty still exists because of the additivity assumption.

If some of the chemicals do not have adequate toxicity information, thus preventing their inclusion in the hazard index, the hazard index may not be reflective of potential hazard from the tank. Consideration of chemicals that do not have toxicity values could significantly increase the hazard index to levels of concern. Professional judgment (e.g., from a toxicologist) is required to determine how to interpret the hazard index for a particular tank.

WORKSHEET 6-16

CALCULATION OF SUBCHRONIC HAZARD INDEX FOR EACH EXPOSURE POINT

INSTRUCTIONS:

Facility ID: ______________

Cluster/Tank System: ______________

Date: ______________

Analyst: ______________

Quality Control: ______________

1. Identify exposure point and subchronic constituents of concern (use additional worksheets if necessary).
2. List the total oral subchronic daily intake (SDI) and total inhalation SDI in the appropriate columns for each chemical (in mg/kg/day).
3. List route-specific subchronic acceptable intake (AIS) values and calculate route-specific SDI:AIS ratios for each chemical.
4. Sum and record route-specific SDI:AIS ratios.
5. Sum and record total (oral plus inhalation) SDI:AIS ratios only if the SDIs for the two routes refer to the same time period. If the sum is greater than 1, it may be possible to separate the ratios according to health endpoint and complete a separate worksheet for each endpoint.

Exposure Point: Facility boundary Population: Future shopping area

Intake Estimates (circle one): Lower Upper Representative

	Chemical	Oral SDI	Oral AIS	Oral SDI:AIS	Inhalation SDI	Inhalation AIS	Inhalation SDI:AIS
1.	Xylene	0.008	0.1	.08	0.004	0.69	0.006
2.	Manganese	0.001	0.53	.002	0	0.003	0
3.							
4.							

Sum of Oral SDI:AIS Ratios = .082

Sum of Inhalation SDI:AIS Ratios = .006

Sum Total of All Ratios = .088

WORKSHEET 6-17

CALCULATION OF CHRONIC HAZARD INDEX FOR EACH EXPOSURE POINT

INSTRUCTIONS:

Facility ID: __________

Cluster/Tank System: __________

Date: __________

Analyst: __________

Quality Control: __________

1. Identify exposure point and chronic, non-carcinogenic constituents of concern (use additional worksheets if necessary).
2. List the total inhalation chronic daily intake (CDI) and total oral CDI in the appropriate columns for each for each chemical (in mg/kg/day).
3. List route-specific chronic acceptable intake (AIC) values and calculate route-specific CDI:AIC ratios for each chemical.
4. Sum and record route-specific CDI:AIC ratios.
5. Sum and record total (oral plus inhalation) CDI:AIC ratios. If the sum is greater than 1, it may be possible to separate the ratios according to health endpoint and complete a separate worksheet for each endpoint.

Exposure Point: Nearest residences

Population: 1,000

Intake Estimates (circle one): Lower Upper Representative

		Oral			Inhalation		
	Chemical	CDI	AIC	CDI:AIC	CDI	AIC	CDI:AIC
1.	Xylene	0.004	0.01	0.04	0.002	0.4	0.005
2.	Lead	0.001	0.22	0.005	0	0.003	0
3.							
4.							

Sum of Oral CDI:AIC Ratios = 0.045

Sum of Inhaltion CDI:AIC Ratios = 0.005

Sum Total of All Ratios = 0.050

6.4.2 Carcinogenic Effects

Risks for potential carcinogens are estimated as probabilities. The carcinogenic potency factor, which is an upper 95 percent confidence limit on the probability of response per unit intake of a chemical over a lifetime (i.e., only 5 percent chance that the probability of response could be greater than the estimated value on the basis of the experimental data used), is used to convert estimated intakes to incremental risk. These carcinogenic potency factors can be found in Appendix C, Exhibit C-4. Because the exposure assessment is conservative, the resultant risk predicted is an upper-bound estimate and may overestimate the actual risk from a release of contaminants from a tank system. This method is used, however, because it is important not to underestimate carcinogenic risk.

For the calculation of incremental risk from relatively low intakes, it can be assumed that the dose-response relationship will be in the linear portion of the dose-response curve. This procedure implies that the slope of the dose-response curve is equivalent to the carcinogenic potency factor (CPF). The relationship between risk and intake is given by the following equation:

$$\text{Risk} = \text{CDI} \times \text{CPF}$$

This equation is valid only at low risk levels. But because the risk-based variance will likely not be granted when chemical intake and estimated carcinogenic risk are large (e.g., above 10^{-4}), it would not be necessary to calculate potential risk accurately. If the tank contains multiple chemicals, assuming individual intakes are small, the risk equation is generalized to the following:

$$\text{Risk} = \Sigma\ (\text{CDI}_i \times \text{CPF}_i)$$

This equation is based on the assumption that there are no synergistic or antagonistic chemical interactions and that all chemicals have the same type of carcinogenic effect. If there is expected to be more than one route of exposure, the total carcinogenic risk is assumed to be additive, that is:

Total carcinogenic risk for a chemical =

$$\text{CDI}_{(\text{inhalation})} \times \text{CPF}_{(\text{inhalation})} + \text{CDI}_{(\text{oral})} \times \text{CPF}_{(\text{oral})}$$

The total potential risk from a hazardous waste tank will be the sum of all the total carcinogenic risks for each chemical contained in the tank at a given point of exposure. Current Agency policy identifies a risk of 10^{-6} as the point of departure within a risk range of 10^{-8} to 10^{-4} for known or suspected carcinogens. A target risk higher than 10^{-6} should be accompanied by an appropriate justification. Worksheet 6-18 is provided for calculating total potential carcinogenic risk.

6.4.3 Other Considerations

The calculations described above are based on a number of assumptions, and there are many uncertainties inherent in the risk assessment process. Results

WORKSHEET 6-18

CALCULATION OF POTENTIAL CARCINOGENIC RISKS FOR EACH EXPOSURE POINT

INSTRUCTIONS:

Facility ID: ______

Cluster/Tank System: ______

Date: ______

Analyst: ______

Quality Control: ______

1. Identify exposure point and potentially carcinogenic constituents of concern (use additional worksheets if necessary).
2. List all exposure routes for each chemical.
3. Record chronic daily intake (CDIs) and carcinogenic potency factors (including carcinogenicity weight-of-evidence; e.g., A, B1, B2, etc.) for each chemical and each exposure route.
4. Multiply the potency factor by the CDI to get the route-specific risk; then sum the route-specific risks for each chemical.
5. Sum all of the chemical-specific risks to give an estimate of total incremental risk due to potential carcinogens.

Exposure Point: On-Site

Population: 20

Intake Estimates (circle one): Lower Upper Representative

	Chemical	Exposure Route	CDI (mg/kg/day)	Carcinogenic Potency Factor (kg/day mg)	Route-specific Risk	Total Chemical-specific Risk
1.	Benzene	Oral	2.5E-4	5.2E-2(A)	1.3E-5	4.4E-5
		Inhalation	1.2E-3	2.6E-2(A)	3.1E-5	
2.						

TOTAL UPPER BOUND RISK = 4.4E-5

that show intakes or risks below the target intakes or risk levels do not necessarily mean that a risk-based variance should be granted. Other available information must first be considered and professional judgment applied to each variance petition.

If indicator chemicals have been used in the risk assessment, it is important to reevaluate the choice of these chemicals and determine whether any information has been uncovered that suggests the need to include other chemicals in the assessment. Care should be taken to include any chemicals that are known to have a synergistic effect. A literature search should be performed to determine if there is any evidence for synergism of the chemicals being evaluated. When specific data are available that support a synergistic effect between two or more chemicals contained in the hazardous waste tank, these data should be considered carefully and the risk assessment modified accordingly. However, the compounds in a mixture may also interfere with the synergism of chemicals. If data on chemical interactions are available but are not adequate to support a quantitative assessment, they should be considered after completion of the risk assessment as factors that may affect the risk.

CHAPTER 7

ENVIRONMENTAL IMPACT EVALUATION

This chapter is designed to be used to evaluate risks to the environment in the event of releases of waste constituents from hazardous waste tanks without secondary containment. To evaluate environmental risks for this final phase of the risk-based variance procedure, a comparison is made between projected environmental exposure levels of indicator chemicals[1] and the harmful levels of these chemicals for animals, plants, and physical structures. The exact nature of this comparison depends upon needs and conditions at individual sites. If water quality criteria are available for all indicator chemicals, this evaluation is based on a comparison of environmental receptor exposure point concentrations, as determined using Worksheet 5-4, to the relevant water quality criteria as described in Section 7.1.

If general water quality criteria are based on irrelevant species or may be affected by site-specific aquatic chemical conditions, then more appropriate site-specific criteria can be derived based on guidance in Section 7.2 for either aquatic or terrestrial exposures. It is not likely that derivation of site-specific criteria will be necessary for most sites. If a criteria is not available for a particular chemical, then the applicant will be expected to include any available relevant environmental information that may exist. Regardless of whether general water quality criteria or site-specific criteria are used, the ratios of environmental receptor exposure point concentrations and criteria for all chemicals at each exposure point are added together based on the assumption that multiple sub-threshold exposures may result in an adverse effect and that the magnitude of the adverse effect will be proportional to the sum of the ratios of the sub-threshold exposures to criteria. Finally, Section 7.3 provides limited guidance on field evaluations that can be used to characterize environmental threats if the criteria comparisons indicate the possibility of environmental harm.

The assessment of environmental risk is generally more complex than a human health evaluation. This additional complexity occurs because the "environment" consists of an assembly of species of plants, animals and microbes as opposed to the single species considered in a human health evaluation. In addition, all of these species have some degree of interaction with many others in the community and with the physical/chemical characteristics of the abiotic environment. At the same time, the endpoint of concern in an environmental evaluation is population maintenance, not individual health as in an evaluation of human health effects.

Species interactions and differences in the endpoints of concern tend to limit the amount of available information which is useful for estimation of environmental impact. As a result, toxicity data for "environmental" species are generally less abundant than for humans. For example, it is not possible to derive toxicity constants for individual chemicals as was done for the human health evaluation. This lack of data requires many simplifying assumptions to complete the evaluation. Extensive extrapolations from chemical analogs or laboratory bioassay data do not accurately reflect chemical impacts at the ecosystem level. However, these data are often the only information available, and, consequently, a large degree of uncertainty results. Thus, many parameters must be ignored or estimated using conservative assumptions, especially when endangered species or unique habitats are considered.

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[1] The list of indicator chemicals include the background chemicals evaluated in Chapter 4.

This environmental impact evaluation compares exposure point concentrations in surface water and ground water estimated in Chapter 5 to quality criteria for water[2]. However, no comparable set of quality criteria for environmental exposure to soil- or sediment-bound chemicals are available. Thus, if these routes of exposure are thought to be important, either a site-specific conversion factor or experimental data may be required to complete the evaluation. Likewise, the degree of projected damage to physical structures will have to be estimated based upon existing corrosion resistence data for the affected structure.

Carcinogenic effects are not considered in the environmental impact evaluation. In the absence of data to the contrary, carcinogens potent enough to result in population perturbations in the ecosystem are assumed to be adequately addressed at lower levels in the human health evaluation. Distinctions between toxicological effects of different chemicals are generally not possible. Therefore, any observed effect which may reduce the lifespan or reproductive potential of an organism or population is considered a hazardous effect.

The basic process of the environmental impact evaluation is illustrated in Exhibit 7-1. In general, potential hazards to the environment are assessed by comparing exposure point concentrations to established standards or guidelines. A field evaluation may be useful to provide information concerning the species present at exposure points, the population sizes, the presence of endangered or threatened species, and the proximity to parkland or human-made structures. This information can be used to determine the scope necessary for the environmental evaluation.

The next step is to list the important chemicals and calculate exposure point concentrations associated with each chemical (see Chapter 5). Note that this list may be a more extensive list of chemicals than that used in the health evaluation described in Chapter 6. The calculations of exposure point concentrations for any chemicals not included in the list of indicator chemicals evaluated in Chapter 6 are based on methods presented in Chapter 5.

These calculated values of exposure point concentrations are then compared with quality criteria previously established by EPA. If site-specific conditions warrant, alternative methods of deriving appropriate criteria values

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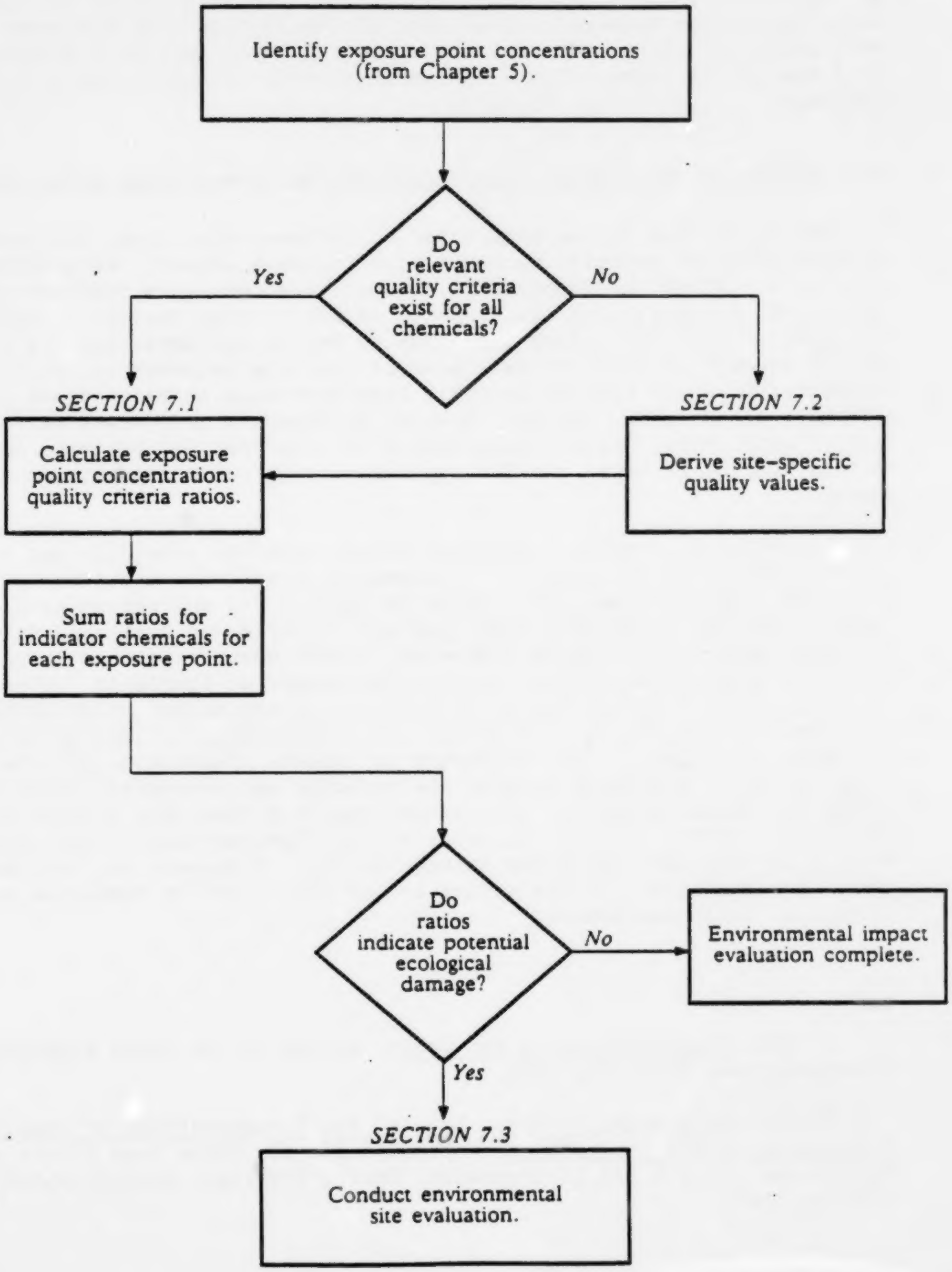
[2] EPA, Quality Criteria for Water, Office of Water Regulations and Standards, 440/5-86-001, 1986.

Exhibit 7-1

OVERVIEW OF ENVIRONMENTAL IMPACT EVALUATION


Identify exposure point concentrations (from Chapter 5).
Do relevant quality criteria exist for all chemicals?
Yes
No
SECTION 7.1
Calculate exposure point concentration: quality criteria ratios.
SECTION 7.2
Derive site-specific quality values.
Sum ratios for indicator chemicals for each exposure point.
Do ratios indicate potential ecological damage?
No
Environmental impact evaluation complete.
Yes
SECTION 7.3
Conduct environmental site evaluation.

are used as presented in Section 7.2. Site-specific adjustment of criteria may be needed because a species at a site is more or less sensitive than those used to determine the national criteria value. Physical and chemical characteristics of the site may ameliorate or enhance the biological availability and/or toxicity of chemicals and could warrant the development of site-specific criteria. In some situations, water quality criteria will not be available for all indicator chemicals and the development of site-specific criteria will be necessary to perform the evaluation. In the event that the evaluation indicates potential environmental harm, Section 7.3 presents guidance on the types of information which will be needed for a risk-based variance.

7.1 COMPARE EXPOSURE POINT CONCENTRATIONS AND QUALITY STANDARDS

The first step in the evaluation of environmental risk, the determination of environmental receptor exposure point concentrations, has been performed in Chapter 5. After the exposure point concentrations have been determined, projected concentrations are compared to EPA's water quality criteria.[3] Consideration of the assumptions made to derive the water quality criteria should be made in order to determine if they are relevant to use for comparison. Water quality criteria were developed to be relevant and useful for most situations. However, unusual differences in species sensitivity or site chemistry may warrant development of site-specific criteria for some sites. Marine criteria are for applications in which exposure occurs in salt water.

For each environmental exposure point, list the chemicals and projected concentrations on Worksheet 7-1. Exposure point concentrations can be obtained from Worksheet 5-4. Refer to Exhibit 7-2 and record each chemical's chronic quality criteria. Water quality criteria are available for only a limited number of chemicals. However, lowest observed effect levels (LOELs) are available for a substantially larger number of chemicals. These concentrations are also listed on Exhibit 7-2 and marked by an asterisk. If a criterion is not listed, use either the chronic LOEL divided by 10 or the acute LOEL divided by 100, whichever is lowest. These divisors are derived from currently available data on the toxicity and ecological effects of chemicals released in the environment, and they take into account the uncertainties due to such variables as test species sensitivity, laboratory test conditions and age-group susceptibility. A support document containing a detailed discussions of the derivation of the values is available from EPA's Office of Toxic Substances.[4]

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[3] EPA, Quality Criteria for Water, Office of the Water Regulations and Standards, 440/5-86-001, 1986.

[4] EPA, Estimating "Concern Levels" for Concentrations of Chemical Substances in the Environment (unpublished), available from Office of Toxic Substances, Health and Environmental Review Division, Environmental Effects Branch, 1984.

WORKSHEET 7-1

COMPARISON OF ENVIRONMENTAL RECEPTOR EXPOSURE POINT CONCENTRATION WITH WATER QUALITY CRITERIA

Facility ID: ____________
Cluster/Tank System: ____________
Date: ____________
Analyst: ____________
Quality Control: ____________

INSTRUCTIONS:

1. List all chemicals for the exposure point.
2. List projected total exposure point concentration from Worksheet 5-4. Indicate whether short-term or long-term concentration.
3. List type (e.g., criteria, LOEL) and value of relevant water quality criteria for each chemical.
4. Divide projected exposure concentration by criteria concentration.
5. Sum the ratios for all chemicals at the exposure point.

Exposure Point: Spring

Concentration (circle one): Short-term Long term

	Chemical	Exposure Point Concentration (mg/l)	Type of Criteria	Quality Criteria Value (mg/l)	Ratio
1.	Arsenic(tri)	0.005 mg/l	Fresh Chronic	0.190 mg/l	0.026
2.	Cadmium	0.005 mg/l	Fresh Chronic	0.0011 mg/l	4.545
3.	Lead	0.001 mg/l	Fresh Chronic	0.0032 mg/l	0.313
4.	Iron	0.250 mg/l	LOEL/10	0.1 mg/l	2.500
				Total:	7.384

EXHIBIT 7-2

ACUTE AND CHRONIC WATER QUALITY CRITERIA[a/] FOR PROTECTION OF FRESHWATER AND MARINE ORGANISMS AND LOEL (LOWEST OBSERVED EFFECT LEVEL) VALUES b/

	Concentrations in ug/l			
	Fresh Acute Criteria; LOEL b/	Fresh Chronic Criteria; LOEL b/	Marine Acute Criteria; LOEL b/	Marine Chronic Criteria; LOEL b/
Acenapthene	1,700*	520*	970*	710*
Acrolein	68*	21*	55*	
Acrylonitrile	7,550*	2,600*		
Aldrin	3.0		1.3	
Alkalinity		20,000		
Ammonia (Total)	15.7	3.9		
Ammonia (Un-ionized)	0.092	0.002		
Antimony	9,000*	1,600*		
Arsenic(pent)	850*	48*	2,319*	13*
Arsenic(tri)	360	190	69	36
Benzene	5,300*		5,100*	700*
Benzidine	2,500*			
Beryllium	130*	5.3*		
BHC	100*		0.34*	
Cadium	3.9	1.1	43	9.3
Carbon Tetrachloride	35,200*		50,000*	
Chlorakyl ethers	238,000*			
Chlordane	2.4	0.0043	0.09	.004
Chlorinated Benzenes	250*	50*	160*	129*
Chlorinated Napththalenes	1,600*		7.5*	
Chlorinated Phenols	500,000*	970	440	
Chlorine	19	11	13	7.5
Chloro 4 Methyl-3-Phenol	30*			
Chloroform	28,900*	1,240*		
Chlorophenol			440*	
Chlorophenol 2	4,380*	2,000*		
Chlorophenol 4			29,700*	
Chromium(Hex)	16	11	1,100	50
Chromium(Tri)	1,700	210	10,300*	
Copper	18	12	2.9	2.9
Cyanide	22	5.2	1	
DDE	1,050*		14*	
DDT	1.1	0.001	0.13	0.001
Demeton		0.1*		0.1*
Dichloroethane	11,800*	20,000*	113,000*	
Dichlorobenzenes	1,120*	763*	1,970*	
Dichloroethylenes	11,600*		224,000*	
Dichlorophenol 2,4	2,020*	365*		
Dichloropropane	23,000*	5,700*	10,300	3,040*

WORKSHEET 7-1

COMPARISON OF ENVIRONMENTAL RECEPTOR EXPOSURE POINT CONCENTRATION WITH WATER QUALITY CRITERIA

INSTRUCTIONS:

1. List all chemicals for the exposure point.
2. List projected total exposure point concentration from Worksheet 5-4. Indicate whether short-term or long-term concentration.
3. List type (e.g., criteria, LOEL) and value of relevant water quality criteria for each chemical.
4. Divide projected exposure concentration by criteria concentration.
5. Sum the ratios for all chemicals at the exposure point.

Facility ID: __________

Cluster/Tank System: __________

Date: __________

Analyst: __________

Quality Control: __________

Exposure Point: Spring

Concentration (circle one): Short-term Long term

	Chemical	Exposure Point Concentration (mg/l)	Type of Criteria	Quality Criteria Value (mg/l)	Ratio
1.	Arsenic(tri)	0.005 mg/l	Fresh Chronic	0.190 mg/l	0.026
2.	Cadmium	0.005 mg/l	Fresh Chronic	0.0011 mg/l	4.545
3.	Lead	0.001 mg/l	Fresh Chronic	0.0032 mg/l	0.313
4.	Iron	0.250 mg/l	LOEL/10	0.1 mg/l	2.500
				Total:	7.384

EXHIBIT 7-2

ACUTE AND CHRONIC WATER QUALITY CRITERIA a/ FOR PROTECTION OF FRESHWATER AND MARINE ORGANISMS AND LOEL (LOWEST OBSERVED EFFECT LEVEL) VALUES b/

	Concentrations in ug/l			
	Fresh Acute Criteria; LOEL b/	Fresh Chronic Criteria; LOEL b/	Marine Acute Criteria; LOEL b/	Marine Chronic Criteria; LOEL b/
Acenapthene	1,700*	520*	970*	710*
Acrolein	68*	21*	55*	
Acrylonitrile	7,550*	2,600*		
Aldrin	3.0		1.3	
Alkalinity		20,000		
Ammonia (Total)	15.7	3.9		
Ammonia (Un-ionized)	0.092	0.002		
Antimony	9,000*	1,600*		
Arsenic(pent)	850*	48*	2,319*	13*
Arsenic(tri)	360	190	69	36
Benzene	5,300*		5,100*	700*
Benzidine	2,500*			
Beryllium	130*	5.3*		
BHC	100*		0.34*	
Cadium	3.9	1.1	43	9.3
Carbon Tetrachloride	35,200*		50,000*	
Chlorakyl ethers	238,000*			
Chlordane	2.4	0.0043	0.09	.004
Chlorinated Benzenes	250*	50*	160*	129*
Chlorinated Napththalenes	1,600*		7.5*	
Chlorinated Phenols	500,000*	970	440	
Chlorine	19	11	13	7.5
Chloro 4 Methyl-3-Phenol	30*			
Chloroform	28,900*	1,240*		
Chlorophenol			440*	
Chlorophenol 2	4,380*	2,000*		
Chlorophenol 4			29,700*	
Chromium(Hex)	16	11	1,100	50
Chromium(Tri)	1,700	210	10,300*	
Copper	18	12	2.9	2.9
Cyanide	22	5.2	1	
DDE	1,050*		14*	
DDT	1.1	0.001	0.13	0.001
Demeton		0.1*		0.1*
Dichloroethane	11,800*	20,000*	113,000*	
Dichlorobenzenes	1,120*	763*	1,970*	
Dichloroethylenes	11,600*		224,000*	
Dichlorophenol 2,4	2,020*	365*		
Dichloropropane	23,000*	5,700*	10,300	3,040*

EXHIBIT 7-2

ACUTE AND CHRONIC WATER QUALITY CRITERIA a/ FOR PROTECTION OF FRESHWATER AND MARINE ORGANISMS AND LOEL (LOWEST OBSERVED EFFECT LEVEL) VALUES b/

	Concentrations in ug/l			
	Fresh Acute Criteria; LOEL b/	Fresh Chronic Criteria; LOEL b/	Marine Acute Criteria; LOEL b/	Marine Chronic Criteria; LOEL b/
Dichloropropene	6,060*	244*	790*	
Dieldrin	2.5	0.0019	0.71	0.0019
Dimethyl Phenol 2,4	2,120*			
Dinitrotoluene	330*	230*	590*	370*
Dioxin(2,3,7,8-TCDD)	0.01*	0.0056*		
Diphenylhdrazine	270*			
Dissolved Oxygen	6,500	4,000		
Endosulfan	0.22	0.056	0.034	0.0087
Endrin	0.18	0.0023	0.037	0.0023
Ethylbenzene	32,000*		430*	
Fluoranthene	3,980*		40*	16*
Guthion		0.01*		0.01*
Haloethers	360*	122*		
Halomethanes	11,000*		12,000*	6,400*
Heptachlor	0.52	0.0038	0.053	0.0036
Hexachlorobutadiene	90*	9.3*	32*	
Hexachlorocyclohexane (Lindane)	2.0	0.08	0.16	
Hexachlorocyclopentadiene	7*	5.2*	7*	
Hexachloroethane	980*	540*	940*	
Iron		1,000*		
Isophorone	117,000*		12,900*	
Lead	82	3.2	140	5.6
Malathion		.01		.01
Mercury	2.4	0.012	2.1	0.025
Methoxychlor		0.03		0.03
Mirex		0.001		0.001
Naphthalene	2,300*	620*	2,350*	
Nickel	1,800	96	140	7.1
Nitrobenzene	27,000*		6,680*	
Nitrophenols	230*	150*	4,850*	
Nitrosamines	5,850*		3,300,000*	
Parathion		0.04		0.04*
PCB's	2.0	0.014	10	0.03
Pentachlorinated Ethanes	7,240*	1,100*	390*	281*
Pentachlorophenol	55*	3.2*	53*	34*
pH		6.5-9		6.5-8.5
Phenol	10,200*	2,560*	5,800*	
Phosphorus Elemental				0.1
Phthalate Esters	940*	3*	2,944*	3.4*

EXHIBIT 7-2

ACUTE AND CHRONIC WATER QUALITY CRITERIA[a/] FOR PROTECTION OF FRESHWATER AND MARINE ORGANISMS AND LOEL (LOWEST OBSERVED EFFECT LEVEL) VALUES b/

	Concentrations in ug/l			
	Fresh Acute Criteria; LOEL b/	Fresh Chronic Criteria; LOEL b/	Marine Acute Criteria; LOEL b/	Marine Chronic Criteria; LOEL b/
Polynuclear Aromatic Hydrocarbons			300*	
Selenium	260	35	410	54
Silver	4.1	0.12	2.3	
Sulfide-Hydrogen Sulfide		2		2
Tetrachlorinated Ethanes	9,320*			
Tetrachloroethane 1,1,2,2		2,400	9,020*	
Tetrachloroethylene	5,280*	840*	10,200*	450*
Tetrachlorophenol 2,3,4,6				440*
Thallium	1,400*	40*	2,130*	
Toluene	17,500*		6,300*	5,000*
Toxaphene	1.6	0.013	0.07	
Trichlorinated Ethanes	18,000*			
Trichloroethylene	45,000*	21,900*	2,000	
Trichlorophenol 2,4,6		970*		
Zinc	320	47	170	58

[a/] EPA has identified many chemicals (primarily metals) as having variable toxicity depending upon water hardness. Applicants will need to consult the Quality Criteria for Water 1986 (EPA, 1986) to identify which chemicals have variable toxicity and for the specific regression equations to calculate quality criteria at ambient water hardness. The criteria presented in this exhibit are based on a water hardness of 100 mg/l.

[b/] LOEL values are reported when insufficient data exist to calculate a water quality criterion and are denoted with an asterisk (*).

For each chemical, divide the projected exposure point concentration by the quality criterion to obtain a ratio of projected to protective concentrations. If quality criteria are not available for one or more of the chemicals, site-specific values must be derived as outlined in Section 7.2 before this worksheet can be completed. When all the criteria values have been finalized, sum the ratios for all chemicals at each exposure point.

If the sum of the ratios is less than or equal to 1.0, there is a low probability of environmental harm. A value between 1.0 and 10 is indicative of possible harmful effects. A value greater than or equal to 10 is an indication of probable environmental harm. This method is similar to the Office of Pesticide Programs' risk assessment method.[5] The main difference between the two methods, however, is that in the Office of Pesticide Programs' method, the effect level is related to a toxic concentration limit, while in the environmental impact evaluation method of the risk-based variance, a lower effect level (i.e., a less severe endpoint) is used for comparison (namely quality criteria for protection of aquatic life).

At this point, an evaluation of the underlying assumptions may be warranted. For example, if the most mobile indicator chemical is used to represent all the indicator chemicals, a question to ask is whether the transport rate of the most mobile chemical is radically different from the other chemicals. If this is the case, the sum of the ratios may be artificially high. Conversely, this analytical method does not take into account the possible impact of synergistic enhancement or antagonistic reduction of toxicity by a mixture of chemicals. The approach assumes that multiple subthreshold exposures result in adverse effects at a magnitude proportional to the sum of the ratios of expected exposures versus acceptable exposures.

A complete summary of levels of uncertainty, assumptions and extrapolations should be included. Also, this summary should include a discussion of the health of the ecosystem at the points of exposure. The health of an ecosystem can be discussed in terms of stressed communities, population diversity, important functional parameters of the community, productivity, and stability. This information may be generated from site surveys or from private, state, or federal information sources.

Human-made structures may also be affected from contamination with hazardous waste. Potential contamination of physical structures is evaluated by comparing estimated exposure point concentrations at the structure to the corrosion resistance of the structural materials[6][7] to individual contaminants. If concentrations of hazardous waste constituents exceed the level that would ensure corrosion resistance of the structural material to a specific chemical, deterioration of the structure may be of concern.

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[5] EPA, Hazard Evaluation Division Standard Evaluation Procedure - Ecological Risk Assessment, Office of Pesticide Programs, 540/9-85-001, 1986.

[6] National Association of Corrosion Engineers, Corrosion Data Survey - Nonmetals Section, (Houston: National Association of Corrosion Engineers, 1975).

[7] National Association of Corrosion Engineers, Corrosion Data Survey - Metals Section, (Houston: National Association of Corrosion Engineers, 1985).

7.2 DERIVATION OF SITE-SPECIFIC CRITERIA

The purpose of this section is to provide guidance to applicants who need to use alternate criteria for calculating concentration ratios because available criteria either do not address or are not relevant for chemicals or conditions at the site. The values derived in this section may be used where local conditions warrant an adjustment (up or down) in existing criteria. When a criterion does not exist for a chemical, provide the concentrations estimated in Chapter 5 and any available toxicity information.

The EPA derives criteria for water quality by the complex manipulation of a toxicity data base for aquatic organisms which is referred to as the national acute toxicity data set. The data set contains verified toxicity concentrations for the organisms listed in Exhibit 7-3. For both fresh and saltwater environments, acute toxicity data for eight families of organisms, acute-chronic ratios for three families, acute toxicity to an algal species or vascular plant species and a measurement of bioconcentration are required to calculate the water quality criteria.

Site-specific criteria development may be justified because species at a given site may be more or less sensitive than those represented in the national criteria document.[8] For example, the national criteria data set contains data for trout, salmon, penaeid shrimp, and other aquatic species that have been shown to be especially sensitive to some chemicals. Because these or other sensitive species may not occur at a particular site, they may not be representative of those species that do occur there. Conversely, a site may have untested sensitive species that are ecologically important and need to be protected.

In addition, differences in physical and chemical characteristics of the site have been demonstrated to ameliorate or enhance the biological availability and/or toxicity of chemicals. For example, alkalinity, hardness, pH, suspended solids and salinity influence the concentration(s) of the toxic form(s) of some heavy metals, ammonia, and other chemicals.

7.2.1 Derivation of Aquatic Criteria

EPA recognizes three methods for calculating site-specific water quality criteria[9] depending on why the site-specific criteria are needed for the site. These methods are as follows: 1) recalculation procedure, which is used if the species used to determine the toxicity data on which the water quality critera are based are not relevant to the site; 2) indicator species contaminants. If concentrations of hazardous waste constituents exceed the level that would ensure corrosion resistance of the structural material to a specific chemical, deterioration of the structure may be of concern.

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[8] EPA, Quality Criteria for Water 1986, Office of Water Regulations and Standards, 440/5-86-001, 1986.

[9] EPA, Waste Qualty Standards Handbook, Office of Water Regulations and Standards, 1983.

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[8] EPA, Quality Criteria for Water 1986, Office of Water Regulations and Standards, 440/5-86-001, 1986.

[9] EPA, Waste Qualty Standards Handbook, Office of Water Regulations and Standards, 1983.

EXHIBIT 7-3

CHEMICAL SPECIFIC TOXICITY INFORMATION IN THE NATIONAL ACUTE TOXICITY DATA SET

I. Fresh Water

Acute toxicity concentrations for
- a Salmonid (trout or salmon)
- a warmwater commercial or recreational fish (bluegill, catfish)
- a third fish species or amphibian
- a planktonic crustacean (cladoceran, copepod)
- a benthic crustacean (ostracod, isopod, crayfish)
- an insect
- a species which is not an arthropod or vertebrate (molluscs, rotifers, annelids)
- a family in any order of insect or phylum not already represented

Acute-chronic ratios for
- at least one fish species
- at least an invertebrate species
- at least one acutely sensitive species

Acute toxicity concentrations for
- a freshwater algal species or vascular plant (if plants are among the aquatic organisms that are most sensitive to the material, results of a test with a plant in another division is also required)

Bioconcentration factor
- for at least one appropriate species

II. Salt Water

Acute toxicity concentrations for
- two vertebrate families
- any crustacean in the Mysid or Penaeid family
- three other non-vertebrate families
- a species which is not a vertebrate or anthropod
- any family not already used

Acute-chronic ratios for
- a fish species
- an invertebrate species
- an acutely sensitive saltwater species

EXHIBIT 7-3 (Continued)

CHEMICAL SPECIFIC TOXICITY INFORMATION IN THE NATIONAL ACUTE TOXICITY DATA SET

Acute toxicity concentrations for	- a saltwater algal species or vascular plant (if plants are among the aquatic organisms that are most sensitive to the material, results of a test with a plant in another division is also required)
Bioconcentration factor	- for at least one appropriate species

III. Other Information

Information on dependence of toxicity of the chemical on environmental factors (e.g., water hardness and metals) procedure, which is used to adjust for differences in water quality that may affect the toxicity and biological availability of hazardous waste at the site; and 3) resident species procedure, which is used to concurrently adjust for species sensitivity and aquatic chemistry effects that may simultaneously occur necessitating criteria adjustment. Details of the three procedures are given in the above reference. These procedures range from relatively simple and straightforward to quite complex laboratory analyses. Professionals trained in aquatic toxicology may be required to perform some of these tests and interpret the results. A brief discussion of the conditions under which these procedures may be used are outlined below to give the applicant an overview of the subject.

Recalculation Procedure

The recalculation procedure allows modifications in the national acute toxicity data set by eliminating data for species that are not resident at the site. This procedure is designed to compensate for any real difference between the sensitivity range of species represented in the national data set and species found at a site. Sufficient toxicity data may be available for other, more relevant species, allowing simple recalculation with the relevant toxicity data. However, elimination of data for this recalculation procedure may result in insufficient data to meet the national minimum data set requirements, in which case additional resident species acute testing in laboratory water is required before this procedure can be used.

Certain families or organisms have been specified to be represented in the National Guidelines[18] acute toxicity minimum data set (e.g., Salmoidae in freshwater and Penaeidae or Mysidae in saltwater). All specified families may not exist at any given site. If this or any other requirement cannot be met because the family or other group (e.g., insect or benthic crustacean in freshwater) is not represented by resident species, select a substitute(s) from a sensitive family represented by one or more resident species to meet the eight family minimum data set requirement. If all the families at the site have been tested and the minimum data set requirements have been met, use the most sensitive resident family mean acute value as the site-specific Final Acute Value (FAV), which is defined as an estimate of the chemical concentration that is not acutely toxic to 95 percent of the species present at the site. No chronic testing is required by this procedure since the acute/chronic ratio will be used with the site-specific FAV to obtain the site-specific Final Chronic Value (FCV). The acute/chronic ratio is the quotient of the mean acute toxicity concentration divided by the mean chronic toxicity concentration for the chemical. Therefore, the site-specific FCV is the ratio of the site-specific FAV to the acute/chronic ratio.

In addition to toxicity values, Final Residual Values (FRV) may also be calculated for areas where the occurrence of elevated contaminants in the flesh of commercially or environmentally important species is possible. For lipid soluble chemicals whose FRVs are based on Food and Drug Administration (FDA) action levels, adjustments in these values based on the percent lipid content of resident aquatic species is appropriate for the derivation of site-specific FRVs. For lipid soluble chemicals, the national FRV is based on an average 11 percent lipid content for edible portions for the freshwater chinook salmon and lake trout and an average of 10 percent lipids for the edible portion for saltwater Atlantic herring. An adjustment for these differences may be necessary, because resident species of concern at any given site may have higher (e.g., Lake Superior siscowet, a race of lake trout) or lower (e.g., many sport fish) percent lipid content than those species used for the national FRV.

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[18] EPA, Quality Criteria for Water 1986, Office of Water Regulations and Standards, 440/5-86-001, 1986.

For some lipid soluble chemicals such as polychlorinated biphenyls (PCB) and DDT, the national FRV is based on wildlife consumers of fish and aquatic invertebrate species rather than an FDA action level because the former provides a more stringent residue level[11]. Since the data base on the effects of ingested aquatic organisms on wildlife species is extremely limited, it would be inappropriate to base a site-specific FRV on resident wildlife species. Consequently, site-specific modifications for these chemicals are based on percent lipid content of resident species consumed by humans.

For the lipid soluble chemicals whose national FRVs are based on wildlife effects, the limiting wildlife species (mink for PCB and brown pelican for DDT) are considered acceptable surrogates for resident avian and mammalian species (e.g., herons, gulls, terns, otter) and a less restrictive modification of the national FRV is not appropriate. The site-specific FRV would be the same as the national value.

Indicator Species Procedure

This procedure is based on the assumption that physical and/or chemical characteristics of water at an exposure site influences biological availability and/or toxicity of a chemical. This procedure is designed to compensate for site water quality characteristics which may affect the biological availability and/or toxicity of a chemical. Major factors affecting aquatic toxicity values of many chemicals, especially heavy metals, have been identified. For example, the carbonate system of natural waters (pH, hardness, alkalinity, and carbon dioxide relationships) has been the most studied and quantified with respect to effects on heavy metal biological availability and/or toxicity to aquatic life.

Acute toxicity in site water and laboratory water is determined using representative species resident at the site, or acceptable non-resident species as indicators or surrogates for species found at the site. The difference between toxicity values determined for the site water and for the laboratory water on which the national criteria were based, expressed as a water effect ratio, is used to convert the national maximum concentration for a chemical to a site-specific maximum concentration from which a site-specific Final Acute Value (FAV) is derived.

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[11] EPA, Quality Criteria for Water 1986, Office of Water Regulations and Standards, 440/5-86-001, 1986.

This procedure also provides three methods for obtaining a site-specific Final Chronic Value (FCV). One method consists of calculating the FCV (no testing required) if a Final Acute/Chronic Ratio for a given chemical is available in the national criteria document.[12J] This ratio is simply divided into the site-specific FAV to obtain the site-specific FCV. The second consists of obtaining the FCV by performing at least two acute and chronic toxicity tests on both fish and invertebrate species (resident or non-resident) in site water. Acute/chronic ratios are calculated for each species, and the geometric mean of these ratios are then divided into the site-specific FAV to obtain the site-specific FCV. The third method consists of obtaining an FCV by performing chronic toxicity tests with at least one fish and one invertebrate (resident or non-resident) in both laboratory water and site water and calculating a geometric mean chronic water effect ratio which is used to modify the national FCV.

Resident Species Procedure

This procedure is designed to compensate concurrently for any real differences between the sensitivity range of species represented in the national data set and for site water conditions that may markedly affect the biological availability and/or toxicity of the material of interest. The purpose is to develop the complete acute toxicity minimum data set using site water and resident species. Derivation of the site-specific maximum and chronic concentration would be accomplished after conducting tests with a sufficient number of resident species in site water. Sufficient species must be tested to satisfy acute toxicity minimum data set requirements. Chronic tests may also be necessary to derive site-specific acute-chronic ratios.

7.2.2 Derivation of Terrestrial Criteria

The evaluation of effects of released chemicals on terrestrial biota is considerably more complex than for aquatic biota. Data on the routes of exposure and chemical transfer between organisms via the food web are very limited. Mammals, birds, and crop plants are given more emphasis in this regard than the other terrestrial species because there are established protocols for testing these species and they have a greater direct economic value than other types of organisms. This emphasis does not necessarily indicate, however, that they are the most important or the best indicators of environmental quality. As with site-specific water quality criteria, terrestrial values may be derived from scientific literature values or laboratory or field data. For mammalian values, data from mammalian (rat) toxicity studies for use in human health evaluations may be used in addition to wild mammal toxicity studies or field studies. Protocols for toxicity testing are specified by EPA in 40 CFR Parts 796, 797, and 798. For the purpose of animal environmental evaluations, only oral or dermal routes of exposure are usually considered relevant.

[12J] EPA, Quality Criteria for Water 1986, Office of Water Regulations and Standards, 1986.

Exposure to hazardous substances may come partly from surface water, partly from contaminated plants, and partly from contaminated prey (in the case of predators). Methodologies for establishing dose levels for terrestrial animals have been detailed by the Office of Pesticide Programs.[13] The methods require a series of data inputs and conversions to derive a concentration level. LD_{50} (lethal dose to 50 percent of test organisms) data are converted to LD_{50}s relative to animal body weight. The quantity of toxicant available to the organism is generated using exposure route information from Chapter 5, and estimates in intake/exposure are developed based on site-specific information concerning relevant species and exposure scenarios. The mass of toxicant actually ingested must be estimated either from extrapolations of laboratory data on indicator species, on resident species, or from actual field studies. These values will vary tremendously with the species tested. For terrestrial plants, dose is relatively straightforward. The environmental receptor exposure point concentration in the ground water or soil is quantified in Chapter 5 and this level is compared to toxic levels (similar to the methods for aquatic organisms). However, few data are available on the toxicity of RCRA hazardous substances to terrestrial vegetation. Thus, measurements will be required or the uncertainties associated with a qualitative assessment must be acceptable.

For environmental impact evaluations, a range of organisms (mammal, bird, vascular plant) and a range of sensitivity must be included. The objective of the study is to obtain "no observed effect levels" (NOELs), or an exposure concentration at which no effect on the organism is observed. The NOEL is distinct from the the "no observed adverse effect level" (NOAEL). In the latter case, effects are observed due to exposure, but they are not considered adverse for the test species.

A safety factor of either 100 or 10 is applied to the lowest NOEL. If available data are for acute toxicity tests, divide the NOEL by 100. If the available data are for chronic toxicity, divide the NOEL by 10. If an endangered species has been identified as utilizing the potentially contaminated environment, apply an additional safety factor of 10 to the data. Use the resultant values to calculate the ratio between exposure point concentration and criteria levels for each exposure point and chemical.

7.3 SITE-SPECIFIC EXPOSURE POINT EVALUATION

In the event that chemical concentrations are projected to be above the water quality criteria as determined in Section 7.1 or site-specific criteria as determined in Section 7.2, a variance permit may still be sought. However, field evaluation of each exposure point where chemical concentrations indicate the possibility of environmental harm will be necessary. The field evaluation will include, but may not be limited to, compilation of species lists (plant and animal), population estimates and diversity indices, population trends for dominant species, projected impacts of the chemicals on population trends, presence of endangered or threatened species, proximity to protected habitats or parkland, recreational use of the area, agricultural or other commercial use of the area, and proximity to buildings, historical sites, utility conveyances or other man-made structures. The species considered must include both permanent residents and migrating species which may utilize the habitat for only part of the year. Some of this information will already have been generated in Chapters 4 and 5 and Section 7.1.

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[13] EPA, Hazard Evaluation Division Standard Evaluation Procedures - Ecological Risk Assessment, Office of Pesticide Programs, 540/9-85-001, 1986.

Surveys for compiling species lists are straightforward and standard methods exist. The level-of-detail of the environmental survey will depend on site-specific needs. Local educational institutions or a state agency may already have the necessary information. The local office of the Fish and Wildlife Service, U.S. Department of Interior, will be able to provide lists of endangered or threatened species, habitats and parklands. Local Chamber of Commerce offices or the appropriate state agency may provide information on agricultural production and value and information on utilities and archeological or historical sites and their nature.

The most difficult aspect of the evaluation will be projecting the impacts on population trends for the operating life of the tank system or beyond, depending upon environmental transport rates. Note that the impacts must be projected based upon present environmental conditions. This evaluation will likely be qualitative because adequate quantitative data are not likely to be available. If the exposure site is already chemically degraded or otherwise stressed, the impact of additional chemical insult must be determined. Factors to take into consideration may include community stability and productivity, impacts of released chemicals on functional parameters (e.g., nutrient cycling, community respiration, reproductive capacity, and carrying capacity), bioaccumulation and food web transfers, and predator-prey relations. Investigation of all of these factors will require the input and/or active participation of knowledgeable professionals in the field (e.g., an ecologist). Field studies of actual community response to chemical exposures may be necessary at some sites. The overriding principle in any field survey, microcosom or field exposure study is to target the most sensitive parameter in the impacted ecosystem.

Environmental impact evaluations can be complex assessments given the variation in number and types of species possible at a site. These calculations should address the limits of uncertainty in any of the measurements and criteria being used and should include an assessment of the assumptions, extrapolations, and data gaps which are inherent in any such study. Exposure point concentrations, chemical intakes, and toxicity and criteria data are all potential sources of uncertainty. On the other hand, most environmental evaluations will not require elaborate scientific procedures or development of specific criteria. Professional judgment is, nevertheless, required in interpreting results of this evaluation to ensure that relevant species are covered and proper criteria have been used. The conclusions of the reports must satisfy the Regional Administrator that the studies are valid, address the proper parameters, and clearly demonstrate a lack of substantial environmental risk posed by the release scenario.

CHAPTER 8

SUMMARIZING THE RISK-BASED VARIANCE APPLICATION

At this point in the risk-based variance application process, the following analyses have been completed:

- a health effects evaluation; and
- an environmental impact evaluation.

This chapter provides guidance for summarizing the results of these evaluations. In general, the summary must provide the following: (1) a rationale for the level of detail of the analysis; (2) a description of each of the steps discussed in Chapters 2 through 7 that were used in the analysis; (3) the worksheets (or their equivalent) listed in Exhibit 8-1; (4) a discussion of all the major sources of uncertainty in the data and estimates (e.g., assumptions, data gaps, model uncertainties, sample variations, detection limits); and (5) a conclusion.

As with the narrative component of the main text of the application, the narrative component of the summary also plays a very important role. It should briefly, but clearly, explain the methods used to generate the data in the application. Recognizing that some reports or portions of reports may be reviewed by the public, and especially by members of the potentially exposed population, care must be taken to summarize the major steps and results of the application in terms that are easily understood.

The following sections briefly describe the major topics that need to be addressed in the summary of the application. Section 8.1 provides guidance on summarizing the source, surrounding area, and exposure characteristics addressed by Chapters 2, 3, 4, and 5. Section 8.2 pertains to Chapter 6 (Health Effects Evaluation), and Section 8.3 addresses Chapter 7 (Environmental Impact Evaluation). The applicant must refer to the individual chapters of this manual to obtain a more thorough discussion of the topics that must be addressed.

8.1 SUMMARIZE THE SOURCE, SURROUNDING AREA, AND EXPOSURE CHARACTERISTICS

This section provides guidance on summarizing Chapters 2, 3, 4 and 5. First, provide a brief site description and include a map indicating the location of the systems or components in the application. Discuss the notice of intent to apply for a variance, and how the estimated timetable (Worksheet 1-1) corresponded with the actual application.

Using worksheets and text generated by Chapter 2, discuss the physical, chemical, and toxicological properties of the waste constituents in the tank systems or components. Note any highly mobile, persistent, or toxic chemicals. Provide the rationale for the indicator chemicals selected. Discuss each chemical not selected and the reasons for not selecting it.

EXHIBIT 8-1

WORKSHEETS FOR SUMMARIZING THE RISK-BASED VARIANCE APPLICATION

Title	Worksheet Number
Timetable for Demonstration of Risk-Based Variance from Secondary Containment	1-1
Scoring for Indicator Chemical Selection: Overall Concentration, Koc, and log Kow Values	2-4
Scoring for Indicator Chemical Selection for Human Health Effects Evaluation: Evaluation of Exposure Factors and Final Chemical Selection	2-8
Scoring for Indicator Chemical Selection for Environmental Impact Evaluation: Evaluation of Exposure Factors and Final Chemical Selection	2-9
Release Volume Profiles Associated with Each Tank System	2-10
Measured Ground-Water Concentrations of Background Chemicals	4-2
Measured Surface Water Concentrations of Background Chemicals	4-6
Potential Human Exposure Pathways	5-1
Potential Environmental Receptor Exposure Pathways	5-2
Contaminant Concentrations at Human Exposure Points	5-3
Contaminant Concentrations at Environmental Receptor Exposure Points	5-4
Comparison of Human Exposure Point Concentrations to Established Standards	6-1
Pathways Contributing to Total Exposure	6-12

EXHIBIT 8-1 (continued)

WORKSHEETS FOR SUMMARIZING THE RISK-BASED VARIANCE APPLICATION

Title	Worksheet Number
Total Subchronic Daily Intake (SDI)	6-13
Total Chronic Daily Intake (CDI)	6-14
Critical Toxicity Values	6-15
Calculation of Subchronic Hazard Index for Each Exposure Point	6-16
Calculation of Chronic Hazard Index for Each Exposure Point	6-17
Calculation of Potential Carcinogenic Risks for Each Exposure Point	6-18
Comparison of Environmental Receptor Exposure Point Concentration with Water Quality Criteria	7-1

Include a brief discussion of the indicator score rankings and other factors used to determine the indicator chemical list. Referring to Worksheet 2-10, discuss the worst-case release volumes and release masses. Identify each tank system component, and briefly describe the release volumes of each. Include the rationale for the chosen release rates. Discuss each tank system's minimum, maximum, and representative release mass profile.

Summarize information gathered from the hydrogeologic characterization of the facility (Chapter 3), including climatic features, geology at and surrounding the site, lithologic and hydrologic features of the unsaturated and saturated zones, ground-water flow directions and rates, and surface water features.

Discuss the surrounding land use, water use, and water quality of both surface waters and ground water in the vicinity of the facility (Chapter 4). Existing background levels of contamination for both surface waters and ground waters should be discussed (Worksheets 4-2 and 4-6). If the facility has experienced a prior release, special attention should be devoted to discussing the effects of the release or releases on ground-water and surface water quality. The applicant should also briefly describe other suspected release sources in the area such as naturally occurring background chemicals, CERCLA sites, other RCRA facilities, and wastewater dischargers; highlight any significant adverse effects on water quality in the area that might be attributable to these sources. Any ongoing remediation efforts in connection with other release sources should also be discussed.

Drawing upon the appropriate worksheets and text generated by Chapter 5, discuss the current and future potential human and environmental exposures associated with the site. If it was determined that neither current nor future potential exposures exist, and, therefore, that no substantial present or potential hazards exist, then clearly summarize the determination of no exposures. If current or future potential exposures do exist, then discuss the highest current and/or future potential exposure. Also, note all other potential exposures. Describe where the exposure points are in relation to the site and how exposure might occur there. Discuss the release sources, transport mechanisms, transport media, exposure routes, and exposed populations. Note any sensitive subpopulations. Describe the fate and transport models that were used to estimate the exposure point concentrations. Provide the rationale for the models chosen and include a brief discussion of the supporting documentation. Timing of exposures (i.e., short-term and long-term) must also be discussed.

8.2 SUMMARIZE THE HEALTH EFFECTS EVALUATION

The first major topic of the health effects evaluation (Chapter 6) is the established quality standards relevant to the site (Worksheet 6-1). Note any acceptable standards that are violated by the estimated chemical concentrations; identify the chemicals involved, the standard and its numerical value, and the numerical values of the lower, representative, and upper concentration estimates. Discuss the standards determined to be most appropriate. Address cumulative (i.e., additive) effects as depicted by the summed ratios of estimated concentrations to acceptable standards and most appropriate standards. Note any summed ratios that exceed one. If an acceptable standard exists for each indicator chemical, indicate this and omit the following summary discussion on intake estimation and noncarcinogenic and carcinogenic risk characterization; proceed instead to the discussion on unquantified health considerations.

Discuss the chemical intake estimates used in the risk characterization (Worksheets 6-12, 6-13, and 6-14). Address the exposure routes, durations, and amounts of intake. Present the total exposure scenarios for each exposure point; include a summary of the relevant route-specific estimated intakes that were combined to give total daily oral intake and total daily inhalation intake.

Chemical toxicity values used to characterize risk must be discussed (Worksheet 6-15). If it was necessary to derive a value based on available toxicological or epidemiological data, provide a brief description of the data and the process used to develop the toxicity value. If a toxicity value was needed but not derived, indicate the reasons for not doing so.

Summarize health risk due to noncarcinogens (Worksheet 6-16 and 6-17). Discuss the lower, representative, and upper estimates of the subchronic and chronic hazard indices calculated for all noncarcinogens for each total exposure point; include each chemical's severity rating (a qualitative scale indicating the severity of the health endpoint; the severity rating scale is given in Exhibit D-1). If an index exceeds one and was recalculated for each health endpoint, summarize this information. Discuss the chemicals that dominate the risks.

Information about carcinogenic risk must be summarized (Worksheet 6-18). First, address the range of total carcinogenic risk at each total exposure point. The weight-of-evidence rating, a qualitative scale based on the amount, relevance, and quality of the toxicity data, must be included. This value can be found in Appendix C. If possible, include some measure of the reliability of the risk information (e.g., 95 percent confidence level, standard deviation). At many sites, some chemicals will be responsible for most of the risk at the site because of high toxicity, large projected releases, or high concentrations. Discuss these especially important chemicals here.

Describe the unquantified health considerations at this point. Address any of the exposure pathways from Worksheet 5-1 that were not considered in the comparisons to standards or the calculations of noncarcinogenic indices or carcinogenic risks. Explain why it was not necessary to consider these exposure pathways.

Sources of uncertainty, such as data gaps, incomplete toxicity information, sample variation, and uncertainty contributed by modeling, and all assumptions, must be discussed. If ranges of uncertainty or confidence levels for particular circumstances are known, they must be included. Finally, any comments that are necessary to explain assumptions, difficulties, results, or conclusions relating to the assessment should be made at this point.

8.3 SUMMARIZE THE ENVIRONMENTAL IMPACT ASSESSMENT

To facilitate presentation and review of the environmental impact assessment, the applicant must first summarize and explain the basis for the quality criteria used in the environmental assessment. When criteria established by EPA (e.g., Exhibit 7-2) have been used, only the selection of fresh water or salt water and chronic or acute values needs to be summarized. When criteria have been derived from other published data or site-specific measurements, a brief presentation of analytical methods and calculations is necessary.

Summarize the ratios of exposure point concentration to ambient quality criteria (Worksheet 7-1). In the event that the overall sum of the concentration/criteria ratios for an exposure point exceeds one, the variance demonstration should include a presentation and discussion of any concentration/criteria ratios calculated for each of the separate toxicity mechanisms of concern.

8.4 CONCLUDE AND SUBMIT THE RISK-BASED VARIANCE APPLICATION

The demonstration of no substantial present or potential hazard to human health and the environment should provide a conclusion by the applicant that addresses the question of substantial present or potential hazard. It should clearly state the rationale for the conclusions that are drawn. If any concentration/standard ratio summations or noncarcinogenic hazard indices exceed one, or if carcinogenic risk exceeds 10^{-6}, or if hazardous substances for which criteria could not be derived are included in the variance demonstration, the applicant must provide further explanation to demonstrate that a risk-based variance is appropriate. The nature of the evidence required for the risk-based demonstration in this case is primarily a function of site-specific conditions, so detailed guidance on the material to be included in the application is not presented here.

The applicant should be aware that even if concentration/standard ratio summations and noncarcinogenic hazard indices are less than one, if carcinogenic risk is less than 10^{-6}, and if all indicator chemicals have toxicity values or standards, an application may still be inadequate in demonstrating no substantial hazard. A demonstration may be inadequate for a variety of reasons. For example, the applicant may have failed to choose appropriate indicator chemicals, exposure pathways, or environmental fate and transport models; or the uncertainty involved with modeling at a particular site may be too high.

Finally, the narratives, worksheets, maps, and appendices generated as described in this volume of the technical resource document, and any other information deemed useful by the applicant, must be bound and delivered to the appropriate U.S. EPA Regional Administrator no later than the statutory deadline stated in the original notice of intent to apply. Failure to submit a complete application by the deadline may result in denial of the application, which will in turn result in a requirement that the applicant install secondary containment for the hazardous waste tank systems or components in question.

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APPENDIX A

PRELIMINARY SCREENING FOR RISK-BASED VARIANCE

A.1 INTRODUCTION

A final rule was enacted July 14, 1986, for new and existing interim status, permitted, and 90-day accumulation tank systems that substantially amends pertinent sections of 40 CFR Parts 260, 261, 262, 264, 265, 270, and 271 (51 Federal Register 25422). One major feature of the rule is the requirement for secondary containment with leak detection (hereafter simply referred to as secondary containment) for most hazardous waste tank systems (40 CFR 264.193 (51 Federal Register 25474)).[1]

The requirement for secondary containment may be waived in one of two ways: (1) a technology-based variance involving the demonstration that alternative design or operating practices will detect leaks and prevent the migration of any hazardous waste beyond a zone of engineering control; or (2) a risk-based variance involving the demonstration that if a release of hazardous waste does occur, there will be no substantial present or potential hazard to human health or the environment. The applicant for the risk-based variance could demonstrate no hazard in one of two ways: (1) that no exposure pathways exist; or (2) that potential exposure point concentrations do not pose a hazard to human health and the environment. The second demonstration involves using appropriate environmental fate and transport models, toxicity characteristics of the waste, estimated exposures, and established environmental quality standards.

The purpose of this appendix is to present a methodology that will help the potential applicant decide whether to apply for a risk-based variance. Potential applicants include owners/operators of interim status, permitted, and 90-day accumulation hazardous waste tank systems who are required to install secondary containment and are considering applying for a risk-based variance. This appendix provides guidance on the use of a relatively simple screening process using readily available information to assist the potential applicant in deciding whether to apply for a variance or install secondary containment. In addition to providing guidance, this screening procedure also assists potential applicants in determining the level of detail that is likely to be needed for the risk-based variance application. For example, ground-water modeling may not be needed if it can be demonstrated that present or potential exposure pathways do not exist.

The purpose of the screening procedure is to provide the applicant with a quick and straightforward procedure for assessing whether to go forward with the variance process. The screening process should take no more than eight hours, although in situations where data must be collected from outside sources it may take longer. It addresses some of the major issues affecting a risk-based variance. The purpose of the screening process is to inform the applicant of situations for which a variance from the secondary containment requirement is not allowed, and of the types of issues and detailed data gathering efforts that will need to be addressed in the actual variance application. The preliminary screening also provides guidance to the applicant on whether to continue with the screening process and variance application.

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[1] All references to regulations for owners and operators of permitted hazardous waste facilities (40 CFR 264) also apply to interim status standards for owners and operators of hazardous waste facilities (40 CFR 265).

It should be noted that professional judgment is needed for using and interpreting this screening procedure. Although every effort has been made in this screening procedure to recommend the appropriate course of action for the potential applicant (i.e., when to apply for a variance and when to install secondary containment), due to highly variable site-specific conditions and constraints in the readily available information used in this screening procedure, not all possible outcomes of a variance application are foreseeable. Therefore, **this screening procedure must be used with caution**. There will be some situations that at first appear to be less than substantial hazards, only to become substantial after further analysis; the reverse, of course, is also true. For example, as identified in the screening questions of Section A.2, hazardous waste tanks located in areas where the depth to ground water is greater than 50 feet are considered to pose a lower hazard than those situated at shallower depths. The recent case of pesticide contamination of the ground water in Hawaii at a depth of 800 feet[2] demonstrates, however, that contamination of deep aquifers can occur in some situations. Thus, although lack of shallow ground water at a site may increase the likelihood that a variance is appropriate, it by no means ensures that a variance application will be granted.

A.2 MAJOR ISSUES AFFECTING A RISK-BASED VARIANCE

The preliminary screening uses a question and answer format to assist the potential applicant in deciding whether to apply for a risk-based variance from the requirements for secondary containment of hazardous waste tank systems. Worksheets are provided to assist the potential applicant in summarizing all relevant information. This screening procedure will assist the applicant in identifying:

- Situations for which secondary containment is not required. Consequently, an application for a variance is not needed.
- Situations for which a variance is not allowed. Consequently, the applicant should not proceed with the variance application.
- Potential necessary future data gathering efforts. If available information is limited, the applicant should reconsider whether to pursue the variance process because

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[2] L.S. Lau and K.R. Green, Subsurface Water Quantity: Organic Chemical Contamination of Oahu Groundwater. Special Report 7.0:85 prepared by Water Research Center, University of Hawaii, for Hawaii State Legislature and the Office of Environmental Quality Control, 1985.

extensive data gathering efforts may be necessary to support a demonstration of no substantial hazard.

- Whether exposure pathways exist. If no exposure pathways exist, then this approach will likely be used for the variance demonstration. Otherwise, the demonstration will likely be based on a demonstration of no hazard to human health and the environment due to the chemical concentrations at exposure points.

Section A.2.1 identifies tank systems and generators that are exempt from the secondary containment requirement and tank systems that are ineligible for a variance from the secondary containment requirement. Section A.2.2 provides guidance on comparing chemical concentrations to established environmental standards. Section A.2.3 identifies situations that are likely to pose more of a hazard to human health and the environment than other situations. This identification is based on surrounding hydrogeological, water use, and water quality characteristics. The purposes of Sections A.2.2 and A.2.3 are to provide the applicant with additional guidance on the types of information that are likely to be required for the application. Section A.2.4 describes a simple procedure to identify exposure pathways. Section A.2.5 provides guidance on whether or not the applicant should continue with the screening procedure and variance application process.

A.2.1 Regulatory Constraints

It is prudent to first determine whether secondary containment is even required for the tank system or component of concern. Hazardous waste tank systems used by generators of small quantities of waste, hazardous waste tank systems that contain no free liquids and are situated inside a building with an impermeable floor, and hazardous waste tank systems that serve as part of a secondary containment system are currently exempt from the secondary containment requirement and, therefore, do not need a variance. Some guidance on determining status is provided in Section A.2.1.1 below; other situations exist, however, that allow regulatory exemptions from the secondary containment requirement. Those applicants unsure of their status concerning secondary containment requirements are urged to examine the appropriate sections of the regulations, or call the EPA RCRA/CERCLA Hotline at (800) 434-9246 or, in Washington, D.C., at (202) 382-3000.

This section addresses conditionally exempt hazardous waste generators and hazardous waste tanks (Section A.2.1.1) and situations that would definitely result in no waiver from the secondary containment requirements due to regulatory constraints. These situations involve new underground tank systems or components (Section A.2.1.2), and time constraints resulting in a late advance notice of intent to apply for a variance (Section A.2.1.4). Questions for determining eligibility for exemptions and denial of applications can be found in Worksheets A-1, A-2, and A-3. Following completion of the worksheets the applicant will know whether further efforts toward obtaining a variance are appropriate. All pertinent issues relating to regulatory constraints are presented in the worksheets. Consequently, the applicant can identify whether a variance is feasible without reading Sections A.2.1.1 through A.2.1.4. These sections are provided for applicants who want additional details on the particular issues.

WORKSHEET A-1

TEST FOR APPLICABILITY OF THE SECONDARY CONTAINMENT REQUIREMENT TO THE FACILITY

Facility ID: ______________

Date: ______________

Analyst: ______________

Quality Control: ______________

INSTRUCTIONS:

1. Starting with the left-most column, determine which generator class the facility is in.
2. Determine which combination of accumulation time and amount stored on site at one time matches the facility conditions.
3. Place a check in the right-hand column of the row that matches the facility conditions. The column second from the right states whether the facility is exempt from the secondary containment requirement.

NEXT STEPS:

If the facility is not exempt, continue with the screening process (Worksheet A-2).

Quantity of Hazardous Waste Generated in a Calendar Month	Accumulation Time	Amount Stored On Site At Any One Time	Exempt/Not Exempt	Check Applicable Category
< 100 kg	n.a.	< 1000 kg	exempt	________
	< 180 days	1000-6000 kg	exempt	________
	> 180 days	> 1000 kg	not exempt	________
	n.a.	> 6000 kg	not exempt	________
100-1000 kg	< 180 days	< 6000 kg	exempt	________
	> 180 days	n.a.	not exempt	________
	n.a.	> 6000 kg	not exempt	________
> 1000 kg	n.a.	n.a.	not exempt	________

Note: If the facility is found to be exempt from the secondary containment requirement according to the table above, but generates acute hazardous waste (as defined in 40 CFR 261.31, 261.32, and 261.33(e)) in excess of 1 kg in a calendar month, or generates less than 1 kg of acute hazardous waste in a calendar month and more than 1 kg is stored on site at one time for more than 180 days, the tanks storing acute hazardous waste are not exempt from the secondary containment requirement. Generators who have questions as to the applicability of the secondary containment requirement to their tank systems should call the EPA RCRA/CERCLA Hotline at (800) 434-9246, or, in Washington, D.C., at (202) 382-3000.

WORKSHEET A-2

TEST FOR APPLICABILITY OF THE SECONDARY CONTAINMENT REQUIREMENT AND ELIGIBILITY FOR A VARIANCE FOR INDIVIDUAL TANKS

Facility ID: ____________

Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

INSTRUCTIONS:

1. For each hazardous waste tank system or component for which a variance is being sought, respond yes or no to the questions below.
2. Begin with question 1 and contine to the next recommended question.

NEXT STEPS:

1. If the tank system or component is determined to be eligible to apply for a variance (i.e., a variance is not forbidden and the tank system or component is not exempt from secondary containment), continue to Worksheet A-3 to determine the date by which a notice of application for a variance must be submitted for the tank system or component.

Question	Response (yes/no)	Next Step If Response Yes	Next Step If Response No
1. Does the tank system serve only as part of a secondary containment system used to collect or contain releases of hazardous waste?	______	Exempt.	Continue to next question.
2. Is the hazardous waste stored in the tank absent of free liquids, as demonstrated by EPA Method 9095?	______	Continue to next question.	Go to question 4.
3. Is the tank system located inside a building with an impermeable floor?	______	Exempt.	Continue to next question.
4. Does tank system ancillary equipment include aboveground piping (exclusive of flanges, joints, valves, and other connections), welded flanges, welded joints and welded connections that are visually inspected daily, sealless or magnetic coupling pumps that are visually inspected daily, or pressurized aboveground piping systems with automatic shut-off devices that are visually inspected daily?	______	Ancillary equipment components identified are exempt from secondary containment. Continue to next question.	Continue to next question.

WORKSHEET A-2 (Continued)

TEST FOR APPLICABILITY OF THE SECONDARY CONTAINMENT REQUIREMENT AND ELIGIBILITY FOR A VARIANCE FOR INDIVIDUAL TANKS

Question	Response (yes/no)	Next Step If Response Yes	Next Step If Response No
5. Is the tank system or component new (i.e., did construction begin after July 14, 1986) or has the tank system been repaired after July 14, 1986 after having leaked or been determined to be unfit for use?	______	Continue to next question.	Tank system or component is eligible for a variance.
6. Is the tank system or component underground?	______	Variance not allowed.	Tank system or component is eligible for a variance.

WORKSHEET A-3

DEADLINES FOR PROVIDING NOTICE OF INTENT TO APPLY FOR A VARIANCE a/

Facility ID: ___________

Tank System: ___________

Date: ___________

Analyst: ___________

Quality Control: ___________

INSTRUCTIONS:

1. The following deadlines have been set for tank owners to provide to the Regional Administrator written notice of intent to apply for a variance. If these deadlines cannot be met, the variance application will be denied.
2. Check only one category that describes the hazardous waste tank in question. Some categories may also require a date to be written in that is determined by the tank age.

NEXT STEPS:

1. If the deadline can be met for providing notice of intent to apply for a variance, continue with the screening tool.

Check Applicable Category	Tank Description	Deadline
________	Tank used to store or treat a waste that became hazardous after January 12, 1987.	Replace January 12, 1987 in the below cutoff dates and age categories with the date the waste was made hazardous, then determine which category the tank falls under and write the deadline date below. Date: _______
________	New tank (construction began after July 14, 1986)	30 days prior to entering a contract for installation.
________	Existing tank (regardless of whether the age of the tank system is known) used to store or treat hazardous waste identified by the following EPA hazardous waste numbers: F020, F021, F022, F026, or F027.	January 12, 1987
For an existing tank system of known and documented age:		
________	Tank system 13 or more years old as of January 12, 1987.	January 12, 1987
________	Tank system less than 13 years old as of January 12, 1987.	Before the tank reaches 13 years in age. Date: _______
For an existing tank system for which the age cannot be documented:		
________	Facility less than 7 years old as of January 12, 1987.	January 12, 1993 (6 years after January 12, 1987)
________	Facility between 7 and 13 years old as of January 12, 1987.	Before the facility reaches 13 years in age. Date: _______
________	Facility greater than 13 years old as of January 12, 1987.	January 12, 1987

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a/ These deadlines are effective in unauthorized states. To the extent these deadlines are applicable under HSWA authorities, they are also applicable in authorized states.

A.2.1.1 Conditionally Exempt Hazardous Waste Generators and Hazardous Waste Tanks

As discussed in the introduction, not all hazardous waste tank owners/operators are required to install secondary containment. This section will identify some situations where conditional exemptions exist. Worksheet A-1 addresses the types of exemptions that may apply to a whole facility. Questions 1 through 4 in Worksheet A-2 are designed to test if individual tank systems or components are exempt from the secondary containment requirement.

One exemption is for those hazardous waste tank owners/operators who, after determining their status based on _all_ of the pertinent regulations, conclude that they are generators of between 100 and 1000 kg per month of hazardous waste and that they accumulate this waste in tanks for less than 180 days (or 270 days if the generator must ship the waste greater than 200 miles) and do not accumulate over 6,000 kg on-site at any time (40 CFR 265.201 (51 _Federal Register_ 25485)). These generators are presently exempt from the secondary containment requirement and, therefore, need not apply for a variance.[3J] Generators of less than 100 kilograms of hazardous waste in a calendar month are also exempt from the secondary containment requirement (as well as all other requirements), as long as they do not accumulate more than 1000 kilograms of hazardous waste on site at any one time (40 CFR 261.5).

Generators of acute hazardous waste, as listed in 40 CFR 261.31, 261.32, and 261.33(e), are subject to different limits on their waste generation rates and on-site accumulation in determining whether they are exempt from secondary containment requirements. As long as no more than one kilogram of acute hazardous waste is generated in a month and no more than one kilogram is accumulated on site at any one time, the waste is not subject to secondary containment requirements (or any other requirements) if it is stored in tanks (40 CFR 261.5). Therefore, generators of acute hazardous waste who utilize tank storage and meet these limitations do not need to apply for a variance from the secondary containment requirement.

Another exemption from the secondary containment requirement is for tanks that are used to store or treat hazardous waste that does not contain free liquids and are situated inside a building with an impermeable floor (40 CFR 264.190 (51 _Federal Register_ 25472)). To demonstrate the absence or presence of free liquids in the stored/treated waste, EPA Method 9095 (Paint Filter Liquids Test), as described in "Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods" (EPA Publication No. SW-846), must be used.

Tanks and sumps, as defined in 40 CFR 260.10 (51 _Federal Register_ 25471), that serve only as part of a secondary containment system to collect or contain releases of hazardous wastes are also exempt from the secondary containment requirement.

[3J] These generators should be aware, however, that EPA has proposed to subject generators of 100 to 1000 kg/mo to the secondary containment requirements (51 _Federal Register_ 36342, October 9, 1986).

A.2.1.2 New Underground Tank System or Component

A new tank system is defined as a tank system that will be used for the storage or treatment of hazardous waste and for which construction commences after July 14, 1986. A risk-based variance from secondary containment is not allowed for new underground tank systems (40 CFR 264.193(g) (51 Federal Register 25475, July 14, 1986)). Questions 5 and 6 in Worksheet A-2 address these types of tank systems.

A.2.1.3 Existing, Underground, Unfit-For-Use Tank System or Component

The definition of an unfit-for-use tank system or component is one from which there has been a leak or spill (40 CFR 264.196 (51 Federal Register 25477)) or that has been determined through an integrity assessment or other inspection to be no longer capable of storing or treating hazardous waste without posing a threat of release of hazardous waste to the environment (40 CFR 260.10 and 264.196 (51 Federal Register 25471 and 25477)). Such a system or component must be immediately removed from service (pursuant to 40 CFR 264.196 (51 Federal Register 25477)). In addition, tank systems with leaks from portions that are not readily accessible for visual inspection must be provided with secondary containment (40 CFR 264.196(e)(4) (51 Federal Register 25477)). If the repaired or replaced tank system or component is underground, a variance is not allowed because it is treated as if it were a new tank system and, therefore, must have leak detection as required by Section 3004(o) of RCRA. Questions 7 through 9 in Worksheet A-2 address this type of tank system.

A.2.1.4 Time Constraints

Because the requirement for installation of secondary containment, in most cases, depends on the age of the tank system, the age of the tank system is important for determining variance eligibility requirements. Also, because time is needed to apply for the risk-based variance and for the Regional Administrator to review the application, the regulations require tank owners/operators to provide advance notice of intent to apply for a variance. The variance may be denied if the notice of intent to submit a variance is not submitted on or before the required date. Worksheet A-3 addresses these time constraints.

For existing tank systems (i.e., where construction began before July 14, 1986), the owner/operator must provide written notice of intent to conduct and submit a demonstration for a variance from secondary containment to the Regional Administrator 24 months prior to the date that secondary containment must be provided (40 CFR 264.193(h)(1)(i) (51 Federal Register 25476)). For new eligible or non-underground tank systems (i.e., where construction began after July 14, 1986), this notice must be provided at least 30 days prior to entering into a contract for installation (40 CFR 264.193(h)(1)(ii) (51 Federal Register 26576)).

If an existing tank system is used to store or treat EPA Hazardous Wastes F020, F021, F022, F023, F026, or F027, then written notice must be provided before January 12, 1987 (40 CFR 264.193(a)(2) (51 Federal Register 25477)). If the age of the existing tank system is known and documented, and the system is 13 or more years old as of January 12, 1987, then written notice must be provided before January 12, 1987; if the tank system is less than 13 years old, then written notice must be provided before the system becomes 13 years old (40 CFR 264.193(a)(3) (51 Federal Register 25474)).

If the age of the tank system is not documented, and the facility is less than seven years old as of January 12, 1987, then written notice must be provided before January 12, 1993; if the facility is seven years old or greater but less than 13 years old as of January 12, 1987, then written notice must be provided before the facility is 13 years old; if the facility is 13 years old or older, then written notice must be provided before January 12, 1987 (40 CFR 264.193(a)(4) (51 Federal Register 25474)).

For tank systems that store or treat materials that become hazardous wastes subsequent to January 12, 1987, the date that the material becomes a hazardous waste must be used in place of January 12, 1987 in the above section of the regulation. In place of January 12, 1993, written notice must be provided six years after the date that the material becomes a hazardous waste (40 CFR 264.193(a)(5) (51 Federal Register 25474)). For example, if the waste becomes hazardous on October 21, 1990, this date should be used wherever January 12, 1987 is found and October 21, 1996 should be used in place of January 12, 1993 to determine when written notice must be provided.

A.2.2 Comparison of Chemical Concentrations to Standards

The purpose of this section is to present a format for comparing the waste constituent concentrations in the tank system to established environmental quality standards. For constituents that have established standards, this comparison will provide an indication of the amount by which they exceed the standard. The greater this difference, the less likely a risk-based variance application will be approved. This is because of the greater likelihood that the exposure point concentration of the chemical will also exceed the established limit. For example, a tank with a waste constituent concentration 1,000 times greater than a standard for that constituent will more likely exceed the standard at the exposure point of concern than a tank with the same waste constituent but with a concentration only 10 times the standard. Of course, chemical- and site-specific properties affecting mobility and persistence of the constituents will greatly affect the present and potential exposure point concentrations.

Comparison to standards involves examining the ratio of the concentration of each waste stream constituent to its corresponding environmental quality standard (if one exists). The standards used for this comparison are the maximum contaminant levels (MCLs), maximum contaminant level goals (MCLGs), federally-approved state water quality standards developed under the Clean Water Act,[4] federal ambient water quality criteria and adjusted criteria

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[4] States with specific numerical ambient water quality standards for toxic chemicals include Alabama, Alaska, Arizona, Arkansas, Delaware, Florida, Illinois, Indiana, Iowa, Kentucky, Louisiana, Minnesota, Mississippi, Montana, Nebraska, New Jersey, New Mexico, North Dakota, Tennessee, Texas, Utah, Vermont, Virginia, West Virginia, and Wisconsin. Appropriate agencies in other states should be consulted to determine if such standards are currently in effect.

(adjusted for drinking water ingestion only), federal drinking water health advisories, and other state criteria. Each of these standards is briefly described at the end of this subsection.

Using Worksheet A-4, record the lower (minimum), upper (maximum), and "representative" chemical concentration for each constituent in the tank system. Determination of the representative concentration should be based on an analysis of all monitoring or inventory data, with the goal being to represent long range trends. It may be appropriate to use a geometric or arithmetic mean of some or all of the samples as the most representative concentration, or it may be more appropriate to choose a concentration that reflects a time trend occurring in the tank. The next step in comparing chemical concentrations to standards is to list all the standards that may exist for each chemical.

For some chemicals, several standards may be available as comparison values. In this case, highlight the most appropriate value for comparison (e.g., with an asterisk on Worksheet A-4). Appropriateness is determined in part by relevance of the criterion to exposure conditions at the site (e.g., exposed population characteristics, duration and timing of exposure, exposure pathways) and in part by how recently the value was developed. Some criteria have been developed recently and may reflect new information compared to older values.

The final steps are to calculate the ratios of the tank constituent concentrations to the standards, sum the ratios for each chemical within a standard (e.g., add all the MCL ratios), and then sum the ratios for each chemical within the most appropriate standards (i.e., add all the most appropriate standard ratios). Although this comparison of chemical concentrations with environmental standards may not provide the applicant with a clear decision on whether to apply for a variance, much of the information will be needed for a risk-based variance demonstration.

Maximum Contaminant Levels (MCLs) are drinking water standards promulgated under the Safe Drinking Water Act. MCLs are listed in Exhibit C-8 and are currently available for 16 specific chemicals (10 inorganics and 6 organic pesticides), total trihalomethanes (covers four chemicals), certain radionuclides, and microorganisms. An MCL is health-based, but it also reflects the technological and economic feasibility of removing the contaminant from the water supply. An MCL for a toxic chemical represents the allowable lifetime exposure to the contaminant for a 70 kg adult who is assumed to ingest two liters of water per day.

Maximum Contaminant Level Goals (MCLGs) are also available and are listed in Exhibit C-9.[5] MCLGs are entirely health-based and, like MCLs,

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[5] MCLGs, which were formally known as recommended MCLs (RMCLs), serve as guidance for establishing drinking water MCLs. EPA recently proposed MCLGs for a group of synthetic organic chemicals, inorganic chemicals, and microorganisms (50 Federal Register 46936-47022, November 13, 1985). EPA also proposed MCLs for the same eight volatile organic chemicals for which final MCLGs were promulgated (50 Federal Register 46902-46933, November 13, 1985).

WORKSHEET A-4

WASTE CONSTITUENT CONCENTRATIONS AND COMPARISON TO STANDARDS

Facility ID: ____________
Date: ____________
Analyst: ____________
Quality Control: ____________

INSTRUCTIONS:

1. List all waste constituents (use additional worksheets if necessary).
2. Record each chemical concentration range and representative value.
3. Refer to Exhibits C-8 through C-12, and/or, for federally-approved state water quality standards, the appropriate state agency, to obtain established water standards. Record the value of the standard, its source (i.e., Maximum Contaminant Level (MCL), MCL Goal (MCLG), federally-approved state standard (FASS), Water Quality Criteria (WQC), or Drinking Water Health Advisories (DWHA)), and any other pertinent information (e.g., whether WQC value refers to a one-day or ten-day exposure). Indicate the most appropriate standards for each chemical with an asterisk.
4. Calculate the ratios of concentrations to standards.
5. Sum the ratios within a standard (e.g., add all MCL ratios), and sum the ratios of the most appropriate standards (no more than one for each chemical).

NEXT STEPS:

1. If several representative concentrations exceed standards by several orders of magnitude, then user may want to reconsider applying for a variance.

Chemical	Chemical Concentration (mg/l)			Established Water Quality Standards		Ratio of Chemical Concentration to Standard		
	Lower	Upper	Repres.	Value (mg/l)	Source	Lower	Upper	Repres.
1. ____________	______	______	______	________	________	______	______	______
				________	________	______	______	______
				________	________	______	______	______
2. ____________	______	______	______	________	________	______	______	______
				________	________	______	______	______
				________	________	______	______	______
3. ____________	______	______	______	________	________	______	______	______
				________	________	______	______	______
				________	________	______	______	______
				Total:	________	______	______	______
					________	______	______	______
					________	______	______	______
					Most appropriate:	______	______	______

represent the allowable lifetime exposure to the contaminant for a 70 kg adult who is assumed to ingest two liters of water per day.

Federally-Approved State Water Quality Standards developed under the Clean Water Act are enforceable standards in that state. At a minimum, states listed in footnote 4 have promulgated at least some federally-approved water quality standards for specific toxic chemicals. The applicant is responsible for determining the availability of applicable state water quality standards for a site.

Federal Ambient Water Quality Criteria for the protection of human health have been developed for 62 out of 65 classes of toxic pollutants (a total of 95 individual chemicals have numerical health criteria). The health criterion is an estimate of the ambient surface water concentration that will not result in adverse health effects in humans. In the case of suspect or proven carcinogens, concentrations associated with a range of incremental cancer risks are provided to supplement a criterion of zero. The federal criteria are non-enforceable guidelines, which many states have used in the development of enforceable ambient water quality standards. Exhibit C-10 lists federal ambient water quality criteria for specific chemicals.

For most chemicals, federal water quality criteria to protect human health have been published for two different exposure pathways. One published criterion is based on lifetime ingestion of both drinking water and aquatic organisms, and the other is based on lifetime ingestion of aquatic organisms alone. The calculations incorporate the assumption that a 70-kilogram adult consumes 2 liters of water and/or an average of 6.5 grams of aquatic organisms daily for a 70-year lifetime. Calculations can be made to derive an adjusted criterion for drinking water ingestion only, based on the two published criteria and the same intake assumptions. Exhibit C-10 presents the published criterion based on lifetime ingestion of both drinking water and aquatic organisms and the adjusted criterion for drinking water only. The adjusted criterion is more appropriate than the non-adjusted criteria for sites with potential contamination of ground-water sources of drinking water because they are based on more realistic exposure assumptions (i.e., exclusion of aquatic organism ingestion as an exposure pathway).

Drinking Water Health Advisories are provided by EPA, in addition to MCLs, to drinking water suppliers as guidance on chemicals that may be encountered in a water system, but for which no federal standard exists. The Office of Drinking Water's nonregulatory health advisories are concentrations of contaminants in drinking water at which adverse effects would not be anticipated to occur. A margin of safety is included to protect sensitive members of the population. The health advisory numbers are developed from data describing noncarcinogenic endpoints of toxicity. They do not quantitatively incorporate any potential carcinogenic risk from such exposure. The Office of Drinking Water has recently developed health advisories for 54 chemicals or chemical groups, and these values are summarized in Exhibit C-11. Under certain circumstances and when the appropriate toxicological data are available, health advisories may be developed for one-day, ten-day, longer-term (several months to several years), and lifetime durations of exposure.

A.2.3 Site Characteristics

This section identifies situations, types of information, and factors that are related to the potential threat to human health and the environment posed by leakage from a hazardous waste tank. This identification is based on hydrogeologic considerations (Section A.2.3.1) and surrounding water use, water quality, and land use considerations (Section A.2.3.2).

As with earlier sections, a question and answer format is used with the worksheets. The questions are intended to be simple, relatively easy to answer, and be directly applicable to assessing potential environmental threat. These questions help identify situations that pose more of a risk than others. Consequently, there is no "next step" as with earlier sections. Comments are provided to assist with the interpretation of answers. It must be kept in mind that the potential risk indicated by the answer to a particular question may be influenced by other factors, as indicated by the answers to other questions and the evaluation of additional factors.

It is recommended at this stage that the preliminary screening questions of this section be answered using the best available (i.e., off-the-shelf) information. Potential data sources for use in obtaining information to answer questions are provided for applicants who want to obtain more accurate information. These sections are intended to indicate to the applicant the type of information that is required for the risk-based variance. Limited availability of these data will require the applicant to gather additional data. Consequently, if many data elements are not available, the applicant may want to reconsider applying for a variance.

A.2.3.1 Hydrogeologic Considerations

Ground water is a valuable resource and often a major source of drinking water. Therefore, the potential for contamination of this resource by leakage from a hazardous waste tank must be carefully evaluated both in the process of determining whether to apply for a risk-based variance from secondary containment and in the review of such an application. Screening questions in this section are designed to evaluate the potential for ground-water contamination by possible leakage from a hazardous waste tank depending on characteristics of the hazardous waste tank location. This evaluation can be addressed through questions about significant hydrogeological characteristics of a site which are important in pollution potential assessment. Hydrogeological considerations comprise the major geologic and hydrologic factors which affect and control ground-water movement into, through, and out of an area, and include geographical and climatic considerations. Generalizations about ground water availability and potential for contamination can be derived from the assessment of these factors.

The screening questions of this section are presented in Worksheet A-5. Whether the answer to a question puts a hazardous waste tank site at a higher or lower risk for potential contamination is identified in the worksheets. Questions are presented in approximate order of decreasing importance in screening considerations. Again, the potential risk indicated by the answer to a particular question may be influenced by other factors, as indicated by the answers to other questions.

WORKSHEET A-5

HYDROGEOLOGIC CONSIDERATIONS

INSTRUCTIONS:

1. Provide a response to each question.
2. If the applicant wants to provide more accurate responses to the questions, the applicant may investigate the listed data sources.

Facility ID: ____________

Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

NEXT STEPS:

1. If the applicant has no knowledge or information relating to the presented questions, or most responses indicate a high risk situation, applicant may want to reconsider applying for a variance.

Question	Response (yes/no)	Data Source	Potential Risk		Comments
			Lower	Higher	
Is the hazardous waste tank located below the water table level?	______	Site Operational Records U.S.G.S. U.S.D.A. (Soil Conservation Service) Local Water Supply Agencies and Companies	--	Yes	Any leakage results in immediate contamination of ground water. Risk associated with a "No" answer is dependent on many other factors.
What is the depth to water at the hazardous waste tank site? a/	______	U.S.G.S. U.S.D.A. (Soil Conservation Service) Local Water Supply Agencies and Companies Well logs or hydrogeological reports.	>50 ft.	<50 ft. g/	Determines the depth of material through which a contaminant must travel to reach an aquifer. The extent of attenuation or removal of contaminant generally increases with increasing depth.
What is the unsaturated zone at a hazardous unsat- waste tank site composed of? b/	______	U.S.D.A. (Soil Conservation Service): Soil Maps Soil Survey Reports	Shale Silt/Clay Glacial Till Karst Limestone c/	Thin or Absent Sand or Gravel	More porous materials such as sand or gravel or the absence of an urated zone between the tank and the ground water indicates faster transport of potential contaminants to ground water.

WORKSHEET A-5 (continued)

HYDROGEOLOGIC CONSIDERATIONS

Question	Response (yes/no)	Data Source	Potential Risk Lower	Potential Risk Higher	Comments
Is the net recharge rate high or low (0-2"/yr) ground- at the site? d/ Generally,	____	U.S.G.S. State Department of Water Resources Local Water Supply Agencies or Companies U.S.D.A. (Soil Conservation Service) NOAA (National Weather Service)	Low	High	Generally, the greater the recharge, the greater the potential for water contamination due to greater transport to water table. areas with unconfined aquifers and high recharge are at greater risk than areas with confined aquifers.
Is the aquifer under a hazardous waste tank site confined or unconfined? e/	____	U.S.G.S: Water Resources Division State Department of Water Resources Local Water Supply Agencies or Companies	Confined	Unconfined	Generally, unconfined aquifers are considered to be at higher risk than confined aquifers due to the ease of contaminant movement into them.
What is the composition of aquifer media at hazardous conta- waste tank site? f/	____	U.S.G.S. State Department of Water Resources Local Water Supply Agencies or Companies	Massive Shale Fractured Bedrock	Karst Limestone Sand and Gravel	Aquifer media exerts the major control over the route and path a minant must follow. If aquifer is very deep, this consideration is much less important.
Is the hazardous waste tank located on or near to a fault(s) or fault zone?	____	U.S.G.S. Geological Maps, Bulletins, or Reports	No	Yes	These features can provide major pathways of migration for contaminant transport to ground water.

WORKSHEET A-5 (continued)

HYDROGEOLOGIC CONSIDERATIONS

Question	Response (yes/no)	Data Source	Potential Risk		Comments
			Lower	Higher	
Is the hazardous waste tank located in a flood-prone area?	______	NOAA (National Weather Service): Flooding levels (elevations U.S.G.S: Topographic maps (site elevations) Federal Insurance Administration: Flood insurance rate map Flood hazard boundary map	No	Yes	Flod-prone areas include: Coastal areas: (coastal barrier islands, eroding shorelines) Channel encroachment areas Wetlands (frequently flooded) 100-year floodplain. In the event of a release, flooding will affect the fate and transport of waste constituents.

a/ Depth to water being the depth to the water surface or water table (i.e., pore spaces filled with water) in an unconfined aquifer, or to top of aquifer if confined.

b/ Unsaturated zone includes soil and rock material down to the water table or aquifer.

c/ Karst topography is characterized by closed depressions or sinkholes, caves, and underground drainage.

d/ Recharge being the amount of water that penetrates the ground surface and reaches the water table. Depends on precipitation, evaporation (evapotranspiration), and unsaturated zone media.

e/ A confined aquifer being one separated from upper materials by a layer of impermeable or low permeability material.

f/ Refers to the consolidated or unconsolidated medium which serves as the aquifer (an aquifer defined as being a medium which will yield sufficient quantities of water for use).

g/ A majority of beneficial use ground water in the U.S. being found at less than 50 feet.

Again, sources for obtaining data to answer the screening questions of this section are identified on the worksheets. This information is not intended to be inclusive of all or even most of the sources for such information. While not identified on the worksheets of Section A.2.3, when the U.S. Geological Survey is listed as a data source, the representative State Geological Survey may also serve as a data source, and may in fact offer a more accessible and extensive (for local information) source of needed data.

A.2.3.2 Surrounding Water Use, Water Quality, and Land Use Considerations

This section presents screening questions that are designed to assess the impact or potential adverse effects to ground-water and surface water quality from failure of and subsequent release from a hazardous waste tank system. Consideration is given to the proximity of drinking water users, proximity of surface water, current and potential usages of ground water, and potential damage to wildlife, crops, and vegetation.

Ground-water questions presented herein are intended to provide a general indication of ground-water use and quality at a hazardous waste tank site. For a more rigorous discussion on characterizing ground waters, readers are directed to Chapter 4 of this document.

Owners or operators of hazardous waste tanks who can determine that ground water surrounding or underlying their site is not a potential source of drinking water and is of limited beneficial use would be more likely to apply for a risk-based variance, since this would indicate no exposure pathway for contamination. It should be noted, however, that a number of states have their own ground-water protection policies, which may differ from the characterization process presented here and thereby affect conclusions reached regarding the appropriateness of a variance based on this characterization.

The screening questions of this section are presented in Worksheet A-6. When answering questions, a two-mile radius from the site or site boundaries should be reviewed.[6] Whether a question's answer puts a facility at a potentially higher or lower risk is identified in the worksheet. Considerations of other factors such as waste (Section A.2.2) and hydrogeologic characteristics (Section A.2.3.1) are especially important for owners or operators who find they are located near ground or surface water of special or beneficial use.

A.2.4 Human Exposure

This section provides guidance, in addition to that provided in Section A.2.3, on examining present or potential exposure pathways that may affect the appropriateness of a variance from hazardous waste tank secondary containment requirements. Identifying exposure pathways is important for two reasons. If there are no present or potential exposure pathways, the applicant will not

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[6] EPA, Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy, Final Draft, Office of Ground-Water Protection, December 1986.

WORKSHEET A-6

SURROUNDING WATER USE, WATER QUALITY, AND LAND USE CONSIDERATIONS

INSTRUCTIONS:

1. Provide a response to each question.
2. If the applicant wants to provide more accurate responses to the questions, the applicant may investigate the listed data sources.

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

NEXT STEPS:

1. If the applicant has no knowledge or information relating to the presented questions, or most responses indicate a high risk situation then the applicant may want to reconsider applying for a variance.

Question	Response (yes/no)	Data Source	Potential Risk		Comments
			Lower	Higher	
Is the ground water at or near the hazardous waste tank site saline (or have a total dissolved solids (TDS) concentration over 10,000 mg/l) to an extent which would not allow drinking or other beneficial uses?	______	Nation Water Well Association Library (Ohio) U.S.G.S.: Basin Investigations NAWDEX a/ Army Corps of Engineers Local sources: Planning Boards Government Councils State Environmental Protection Offices State Universities	Yes	No	If yes, and is hydrogeologically isolated and is of limited beneficial use, may be appropriate to continue screening and variance process.
Is ground water at a site considered to be ecologically vital (i.e., does ground water supply a unique terrestrial or aquatic habitat associated with surface water bodies that if polluted would destroy a unique habitat)?	______	U.S. Fish and Wildlife Service State Endangered Species Coordinator National Park Service U.S. Forest Service U.S. Bureau of Land Management Army Corps of Engineers	No	Yes	If ground water is ecologically vital a successful variance demonstration is unlikely.
Sensitive ecological systems include:					
a) Does ground water at a site supply a habitat for an endangered or threatened species of animals and/or plants?	______		No	Yes	Pursuant to the Endangered Species Act of 1973.

WORKSHEET A-6 (continued)

SURROUNDING WATER USE, WATER QUALITY, AND LAND USE CONSIDERATIONS

Question	Response (yes/no)	Data Source	Potential Risk		Comments
			Lower	Higher	
b) Is hazardous waste tank located in wetlands?	_______		No	Yes	Wetlands are ecologically sensitive as they support vegetation adapted for life in saturated soil conditions. May be protected under state statutes, the Clean Water Act, or Executive Order 11990.
c) Is hazardous waste tank located in a coastal area?	_______		No	Yes	May be regulated under the Coastal Zone Management Act, or State Coastal Zone Management Programs.
d) Is hazardous waste tank located in any other sensitive environmental area -- such as watersheds selected by state and local governments for protection?	_______		No	Yes	
Is ground water at or near a hazardous waste tank site "irreplaceable"?	_______	Local Water Supply Agencies and Companies	No	Yes	If ground water is irreplaceable and highly vulnerable to contamination, a successful variance demonstration is unlikely.
This can be assessed by the following questons:					
a) Does ground water serve a substantial population?	_______		No	Yes	A substantial population being approximately 2500 people within or near the 2-mile review radius. b/
b) Is ground water of surrounding hazardous waste tank site located in areas where there is no alternative source of drinking water or an insufficient alternative source for a substantial population?	_______		No	Yes	Includes islands, peninsulas, and isolated ground water over bedrock.

WORKSHEET A-6 (continued)

SURROUNDING WATER USE, WATER QUALITY, AND LAND USE CONSIDERATIONS

Question	Response (yes/no)	Data Source	Potential Risk Lower	Potential Risk Higher	Comments
Is ground water at or near hazardous waste tank site located in an aquifer designated as a Sole Source Aquifer under the Safe Drinking Water Act?	______	Local Water Supply Agencies and Companies	No	Yes	If yes, potential risk is greater.
Is ground water at or near the site a current or potential source of drinking water?	______	Local Water Supply Agencies and Companies	No	Yes	If yes, potential risk is greater.
Can be assessed by: a) Are there operating drinking water wells (or springs) in the area (within the 2-mile review radius)? b) Would a well or spring in the area be capable of yielding a quantity of drinking water sufficient for the needs of an average family (150 gal/day)?					
Is the hazardous waste tank located near a scenic river or recreational area such that leakage of hazardous waste would adversely affect the area?	______	National Park Service County Recreation Department	No	Yes	Such areas may be protected under State statutory and/or regulatory authority.
Are there agricultural lands located in the area of the hazardous waste tank?	______	U.S. Department of Agriculture (Soil Conservation Service)			
If so, can potentially adverse effects be identified if leakage occurs from a hazardous waste tank?	______		No	Yes	Protection policies are identified in the USDA Farmland Protection Policy and the EPA's "Policy to Protect Environmentally Significant Agricultural Lands."

WORKSHEET A-6 (continued)

SURROUNDING WATER USE, WATER QUALITY, AND LAND USE CONSIDERATIONS

Question	Response (yes/no)	Data Source	Potential Risk		Comments
			Lower	Higher	
Is hazardous waste tank located such that releases could migrate directly to drinking water or a drinking water supply?	______	Local Water Supply Agencies and Companies	No	Yes	If yes, can pose a threat to human health.
Does ground water at or near a hazardous waste site discharge to surface water bodies that serve as a drinking water supply	______	U.S.G.S. Basin Investigations NAWDEX a/ Local Water Supply Agencies and Companies	No	Yes	If yes, surface-water quality may be degraded.

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a/ National Water Data Exchange

b/ Source: EPA, Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy, Office of Ground-Water Protection, December 1986.

need to demonstrate that containment concentration levels do not pose a substantial hazard to human health and the environment. If, on the other hand, exposure pathways are identified, then this information will be useful for the risk-based variance demonstration.

An exposure pathway consists of four necessary elements: (1) a source and mechanism of chemical release to the environment; (2) an environmental transport medium (e.g., ground water, surface water) for the released chemical; (3) a point of potential human contact with the contaminated medium (referred to as the exposure point); and (4) a human exposure route (e.g., drinking water ingestion) at the exposure point. Exhibit A-1 illustrates the elements of an exposure pathway. Each pathway therefore describes a unique mechanism by which a population or an individual is exposed to contaminants originating from a site. The overall risks posed by a site are a composite of the set of individual pathway risks. Risks for individual pathways, however, may not be additive because they may represent risks to different populations.

The analysis described here is a first-cut organization of the relevant site information so that major exposure pathways can be defined. It is not intended as a time-consuming task in the overall screening process. Iterations of this procedure for the variance application will confirm the important exposure pathways.

Although all four elements are necessary to identify an exposure pathway, for this preliminary screening process, the applicant can assume the chemical release is due to either a catastrophic event or a slow leak due to a seam crack or corrosion hole. The necessary steps for the remaining three elements are described below.

- Identify Environmental Transport Medium. Using professional judgment and knowledge of the surrounding environment, the applicant should determine whether or not ground water or surface water is nearby.

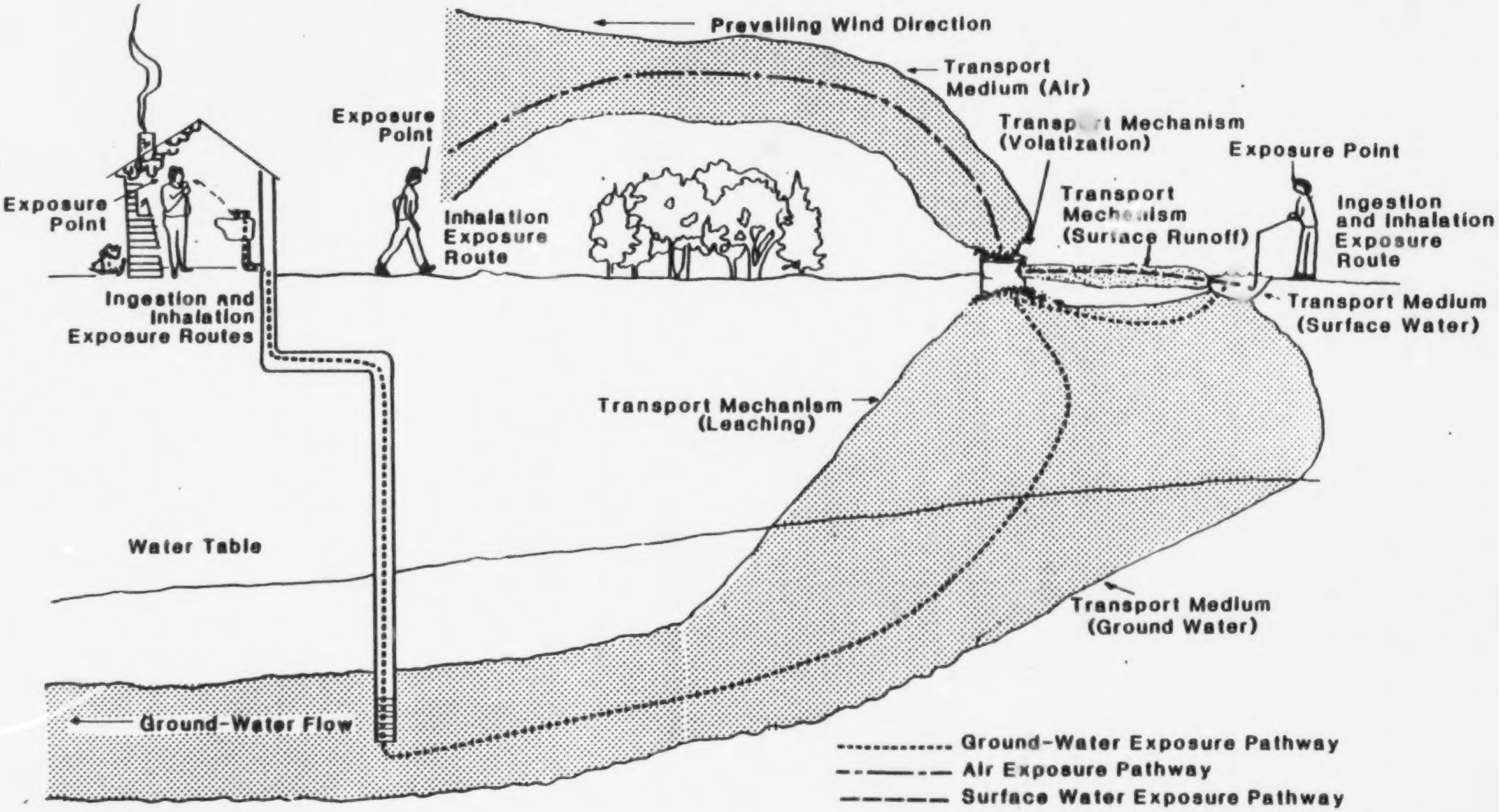
- Identify Potential Exposure Points. The applicant needs to identify the point of future use of ground water and/or surface water that would result in the highest individual exposure (usually the facility boundary) as well as the point of current use of ground water and/or surface water that would result in the highest individual exposure.

- Identify populations that could potentially be exposed. The applicant needs to identify the population that may be exposed. The exact number of people is not necessary at this point, but the applicant should identify whether the source is or will be used to serve a large municipality or private wells. In addition, the applicant should identify if a sensitive population, such as elderly people or children, is a large portion of the potentially exposed population.

Worksheet A-7 provides a matrix to screen potential exposure pathways associated with ground water and surface water. First, identify if ground or surface water is nearby. Then identify if potential exposure points (e.g.,

Exhibit A-1

ILLUSTRATION OF TYPICAL EXPOSURE PATHWAYS*


Prevailing Wind Direction
Transport Medium (Air)
Transport Mechanism (Volatization)
Exposure Point
Exposure Point
Inhalation Exposure Route
Exposure Point
Transport Mechanism (Surface Runoff)
Ingestion and Inhalation Exposure Route
Ingestion and Inhalation Exposure Routes
Transport Medium (Surface Water)
Transport Mechanism (Leaching)
Water Table
Transport Medium (Ground Water)
Ground-Water Flow
Ground-Water Exposure Pathway
Air Exposure Pathway
Surface Water Exposure Pathway

*For the purposes of the screening process, secondary containment is not expected to appreciably decrease risk from direct air exposure: therefore, it is only included here for illustrative purposes.

WORKSHEET A-7

SCREENING OF POTENTIAL EXPOSURE PATHWAYS

Facility ID: ____________
Date: ____________
Analyst: ____________
Quality Control: ____________

INSTRUCTIONS:

1. List all release sources and mechanisms by release medium.
2. Describe the nature of the exposure point and its location with respect to release source (e.g., nearest potable well to release site, 300 feet NW). Denote significant exposure points with an asterisk.
3. List exposure route (e.g., ingestion).
4. Report the number of people potentially exposed at the exposure point.
5. Determine number, location, and nature of sensitive population.
6. Mark where exposure pathways are complete (i.e., where release source, transport medium, exposure point, and exposure route all exist).

Release/ Transport Medium a/	Release Source/ Mechanism	Exposure Point	Exposure Route	Number of People	Sensitive Population	Pathway Complete
Ground water						
Surface water						

---

a/ Direct air exposure need not be considered because secondary containment generally would not significantly reduce risk due to direct air exposure. For aboveground tank systems containing highly volatile constituents, however, secondary containment, by restricting the surface area over which a release could spread, would reduce the volatilization rate of the constituent and, hence, the risk from direct air exposure.

facility boundary, private wells, irrigation wells) exist and the number of potentially exposed individuals. A complete exposure pathway is one that has all necessary components: a mechanism of chemical release (e.g., catastrophic release), environmental transport medium (e.g., ground water or surface water), a potential exposure point, and an exposure route (e.g., ingestion of contaminated drinking water by the exposed population).

Upon completion of Worksheet A-7 the applicant should carefully review the information. In particular, the applicant should consider the reliability of the information presented in the worksheet. For example, the applicant may know of some nearby private wells and a large development complex farther from the tank facility. The applicant should not consider the conclusions reached from the worksheet to be reliable if the worksheet does not reflect knowledge of the drinking water source for the development complex.

The purpose of the worksheet is to provide the applicant with a preliminary indication of the likelihood that a variance will be granted and to help the applicant identify which approach should be taken to apply for a risk-based variance. For example, if the applicant is unable to identify an exposure pathway, then the applicant will likely focus the variance on the demonstration of no exposure pathways. Alternatively, if an exposure pathway is identified and the potentially exposed population is large, the applicant may decide to forego the variance process.

A.2.5 Summary of Screening Process

The issues affecting a risk-based variance, most of which are addressed in the above sections, are inherently related and, in many ways, overlapping. This summary compiles these issues so that the potential applicant for a risk-based variance from secondary containment may more easily determine the next course of action; i.e., whether to not apply for a variance (due to being exempt from secondary containment), install secondary containment, or apply for a variance.

Secondary Containment Not Required. Certain exemptions, discussed in Section A.2.1.1, result in secondary containment not being required. Consequently, an application for a variance is not needed. These situations are summarized below:

- Generators of between 100 and 1000 kg per month of hazardous waste who accumulate the waste for less than 180 days (or 270 days if the generator must transport the waste greater than 200 miles);
- Generators of less than 100 kg per month of hazardous waste who accumulate less than 1,000 kilograms of waste;
- Generators of acute hazardous waste that generate less than one kilogram of acute hazardous waste in a month and accumulate no more than one kilogram on site at a time;

- Tanks that do not contain free liquids and are located in buildings with impermeable floors; and
- Tanks and sumps that serve only as part of a secondary containment system.

Variance Not Allowed. Certain tank systems must comply with the secondary containment requirements. Consequently, for these tank systems a variance is not allowed. These tank systems were addressed in Sections A.2.1.2 and A.2.1.3 and are summarized below:

- New underground, hazardous waste tank systems or components;
- Existing, underground, unfit-for-use tank systems or components; and

Potential Necessary Future Data Gathering Efforts. The type of information that is likely to be required for a demonstration of no substantial hazard and/or no exposure pathway was presented in Sections A.2.2 and A.2.3. It should be noted that these sections only highlight the areas for which more detailed information is likely to be required. If the applicant has limited detailed information relating to these areas, then the applicant may want to reconsider applying for a variance. Several options for obtaining more detailed information are as follows:

- Chemical concentrations at exposure points[7] -- surface water or ground-water release modeling;
- Hazardous and unstable terrain characteristics -- surveying, topographic map, geologic map;
- Hydrogeologic characteristics -- hydrogeologic study, including the installation of observation wells and stratigraphic boreholes such that field tests can be conducted; and[8]
- Surrounding water use and water quality -- conduct procedure as outlined in Chapter 4 of this document.

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[7] Section A.2.2 was based on a comparison of chemical concentrations in the tank to environmental quality standards. The purpose was to provide the applicant with an indication of the degree to which tank hazardous constituent concentrations are above or below the standards. If the concentrations in the tank are below the standards, then the applicant will probably not need to determine chemical concentrations at exposure points.

[8] The amount of data necessary to characterize the stratigraphic units within the unsaturated and saturated zones will increase with the increasing heterogenicity of the zones.

Focus of Variance Application. The applicant can demonstrate no substantial present or future potential hazard in one of two ways: 1) demonstrating that no present or potential exposure pathways exist; or 2) using appropriate environmental fate and transport models, toxicity characteristics of the waste and estimated exposures to assess risks and demonstrate that the concentration levels do not pose a hazard to human health and the environment. Section A.2.4 presented a simplified procedure to identify exposure pathways. If the applicant has confidence in the results of the procedure then the applicant can identify the likely focus of the variance application. If the applicant is unsure of the results, but believes that no exposure pathways exist, the applicant may want to initially pursue this approach for the variance application as described in Chapter 5 of the guidance manual.

The Agency is developing a screening tool program for use on an IBM compatible personal computer. The purpose of this screening tool will be to provide a preliminary indication of whether a tank system poses substantial risk to human health and the environment. The screening tool will use straightforward conservative, ground-water transport and exposure models. These models will require information that is more extensive and less accessible than that required for Appendix A. The Agency intends to make this program available to Regional Administrators and variance applicants in the near future. If the Agency is able to provide this program to the public, EPA will publish a Notice of Availability in the Federal Register.

APPENDIX B

INFORMATION SOURCES FOR ENVIRONMENTAL AND HYDROGEOLOGIC INFORMATION

Federal Agencies

U.S. Environmental Protection Agency, Headquarters (U.S. EPA)
--Office of Water Enforcement and Permits
--Office of Water Regulations and Standards
--Office of Water Programs Operations
--Office of Drinking Water
--Office of Ground-Water Protection
401 M Street, S.W.
Washington, DC 20460
(202) 755-9112

U.S. Geological Survey (U.S.G.S)
Water Resources Scientific Information Center
425 National Center
Reston, VA 22902
(702) 860-7455

U.S. Department of Agriculture (U.S.D.A)
--Agricultural Extension Service
--Soil Conservation Service
Washington, DC 20250
(202) 447-2791

Regional EPA Offices

Region I
Water Management Division
John F. Kennedy Federal Building
Boston, MA 02203
(617)223-7210

Region II
Water Management Division
26 Federal Plaza
New York, NY 10278
(212) 264-2525

Region III
Water Management Division
841 Chestnut Street
Philadelphia, PA 19107
(215) 597-9800

Region IV
Water Management Division
345 Courtland Street, NE
Atlanta, GA 30365
(404) 881-4727

Region V
Water Division
230 South Dearborn Street
Chicago, IL 60604
(312) 353-2000

Region VI
Water Management Division
1201 Elm Steet
Dallas, TX
(214) 767-2600

Regional EPA Offices (cont'd)

Region VII
Water Management Division
726 Minnesota Avenue
Kansas City, KS 66101
(913) 236-2800

Region VIII
Water Management Division
One Denver Place
919 18th Street Suite 300
Denver, CO 80202-2413
(303) 293-1603

Region IX
Water Management Division
215 Fremont Street
San Francisco, CA 94105
(415) 974-8071

Region X
Water Division
1200 Sixth Avenue
Seattle, WA 98101
(206) 442-5810

State Agency Contacts[1/] and Federal Agency State Offices

Alabama

Department of Public Health
Environmental Health Administration
Public Water Supply Division
Montgomery, AL 36130

Water Improvement Commission
749 State Office Building
Montgomery, AL 36130

U.S. Geological Survey
Water Resources Division
University of Alabama
Oil & Gas Bldg - Room 202
P.O. Box V
Tucaloosa, AL 35486
(205) 752-8104

Geological Survey of Alabama
P.O. Drawer O
University, AL 35486
(205) 349-2852

[1/] Source for State Agency Contacts: Wendy Gordon, A Citizens Handbook on Groundwater Protection, (New York: Natural Resources Defense Council, 1984), pp. 162-170.

State Agency Contacts and Federal Agency State Offices (cont'd)

U.S. Soil Conservation Service
State Conservation Office
Wright Building
138 South Gay Street
P.O. Box 311
Auburn, AL 36830
(202) 821-8070

Alaska

Water Quality and Environmental Sanitation Division
Alaska Department of Environmental Conservation
Pouch O
Juneau, AK 99811

Division of Forest, Land and Water Management
Alaska Department of Natural Resources
323 East Fourth
Anchorage, AK 99501

Alaska Division of Geology and Geophysical Surveys
3001 Porcupine Drive
Anchorage, AK 99501
(907) 279-1433

U.S. Soil Conservation Service
State Conservation Office
Suite 129, Professional Building
2221 E. Northern Lights Boulevard
Anchorage, AK 99504
(907) 276-4246

U.S. Geological Survey
Water Resources Division
218 E. Street
Anchorage, AK 99501
(907) 271-4138

Arizona

Planning Division
Arizona Department of Water Resources
222 North Central, Suite 850
Phoenix, AZ 85004

State Agency Contacts and Federal Agency State Offices (cont'd)

Larry D. Fellows
Arizona Bureau of Geology and Mineral Technology
Geological Survey Branch
845 N. Park Avenue
Tucson, AZ 85719
(602) 626-2733

U.S. Soil Conservation Service
State Conservation Office
230 N. 1st Avenue
3008 Federal Building
Phoenix, AZ 85025
(602) 261-6711

U.S. Geological Survey
Water Resources Division
Federal Building
301 W. Congress Street
Tucson, AZ 85701
(602) 792-6671

Arkansas

Soil and Water Conservation Commission
Arkansas Department of Commerce
818 West Capital Avenue, Building A
Little Rock, AR 72202

Arkansas Geological Commission
Vardelle Parham Geological Center
3815 W. Roosevelt Road
Little Rock, AR 72204
(510) 371-1488

U.S. Soil Conservation Service
State Conservation Office
Federal Building, Room 5029
700 West Capitol Street
P.O. Box 2323
Little Rock, AR 72203
(501) 378-5445

U.S. Geolgoical Survey
Water Resources Division
Federal Office Bldg - Room 2301
700 West Capitol Avenue
Little Rock, AR 72201
(501) 278-6391

State Agency Contacts and Federal Agency State Offices (cont'd)

California

California Department of Water Resources
P.O. Box 388
Sacramento, CA 95802

California Division of Mines and Geology
California Department of Conservation
1416 9th St., Room 1341
Sacramento, CA 95814
(916) 445-1923

U.S. Soil Conservation Service
State Conservation Office
2828 Chiles Road
Davis, CA 95616
(916) 758-2200 ext. 210

U.S. Geological Survey
Water Resources Division
855 Oak Grove Avenue
Menlo Park, CA 94025
(415) 323-8111

Colorado

Colorado Water Resources Division
Department of Natural Resources
1313 Sherman Street
Room 818
Denver, CO 80203

Colorado Water Quality Division
Department of Helath
4210 East 11th Avenue
Denver, CO 80220

Colorado Geological Survey
1313 Sherman St., Room 715
Denver, CO 80203
(303) 839-2611

U.S. Soil Conservation Service
State Conservation Office
2490 W. 26th Avenue
P.O. Box 17107
Denver, CO 80217
(303) 837-4275

State Agency Contacts and Federal Agency State Offices (cont'd)

U.S. Geological Survey
Water Resources Division
Building 53
Denver Federal Center
Lakewood, CO 80225
(303) 234-5092

Connecticut

Connecticut Natural Resources Center
Department of Environmental Protection
State Office Building, Room 553
Hartford, CT 06115

Connecticut Geological & Natural History Survey
State Office Building, Room 553
165 Capitol Avenue
Hartford, CT 06115
(203) 566-3540

U.S. Soil Conservation Service
State Conservation Office
Mansfield Professional Park
Route 44A
Storrs, CT 06268
(203) 429-9361/9362

U.S. Geological Survey
Water Resources Division
135 High Street - Room 235
Hartford, CT 06103
(203) 244-2528

Delaware

Delaware Department of Natural Resources
and Environmental Control
Water Supply Branch
Edward Tatnall Building
P.O. Box 1401
Dover, DE 19901

Delaware Geological Survey
University of Delaware
Newark, DE 19711
(302) 738-2833

State Agency Contacts and Federal Agency State Offices (cont'd)

U.S. Soil Conservation Service
State Conservation Office
Treadway Towers, Suite 2-4
9 East Loockerman Street
Dover, DE 19901
(302) 678-0750

U.S. Geological Survey
Water Resources Division
Subdistrict-Dist. Office/MD
Federal Building - Room 1201
Dover, DE 19901
(302) 734-2506

Florida

Flordia Department of Environmental Regulation
Division of Environmental Programs
Groundwater Section
2600 Blair Stone Road
Tallahassee, FL 32301

Florida Bureau of Geology
903 W. Tennessee St.
Tallahassee, FL 32304
(904) 488-4191

U.S. Soil Conservation Service
State Conservation Office
Federal Building
P.O. Box 1208
Gainesville, FL 32602
(904) 377-8732

U.S. Geological Survey
Water Resources Division
324 John Knox Rd. Suite F-240
Tallahassee, FL 32303
(904) 386-1118

Georgia

Georgia Department of Natural Resources
Water Protection Branch
270 Washington Street, S.W.
Atlanta, GA 30334

State Agency Contacts and Federal Agency State Offices (cont'd)

Georgia Department of Natural Resources
Environmental Protection Division
Geological Survey and Water Resources Section
270 Washington Street, S.W.
Atlanta, GA 30334

Georgia Department of Natural Resources
Geological & Water Resources Division
19 Dr. Martin Luther King, Jr. Drive, S.W.
Atlanta, GA
(404) 656-3214

Soil Conservation Service
State Conservation Office
Federal Building
355 E. Hancock Avenue
P.O. Box 832
Athens, GA 30603
(404) 546-2274

U.S. Geological Survey
Water Resources Division
Suite B
6481 Peach Tree, Indust. Blvd
Doraville, GA 30360
(404) 221-4858

Hawaii

Hawaii Division of Water and Land Development
Department of Land and Natural Resources
P.O. Box 373
Honolulu, HI 96809
(808) 548-7533

U.S. Soil Conservation Service
State Conservation Office
300 Ala Moana Blvd.
Room 4316
P.O. Box 5004
Honolulu, HI 96850
(808) 546-3165

U.S. Geological Survey
Water Resources Division
P.O. Box 50166
300 Ala Moana Blvd.-Rm 6110
Honolulu, HI 96850
(808) 546-8331

State Agency Contacts and Federal Agency State Offices (cont'd)

Idaho

Idaho Department of Water Resources
State House
Boise, ID 83720

Idaho Bureau of Mines & Geology
Moscow, ID 83843
(208) 885-6785

U.S. Soil Conservation Service
State Conservation Office
304 North 8th Street, Room 345
Boise, ID 83702
(208) 384-1601 ext. 1601

U.S. Geological Survey
Water Resources Division
P.O. Box 2230
Idaho Falls, ID 83401
(208) 526-2438

Illinois

Illinois Environmental Protection Agency
Public Water Supply Division
2200 Churchill Road
Springfield, IL 62706

Illinois State Water Survey
605 E. Springfield Avenue
P.O. Box 5050, Station A
Champaign, IL 61820

Illinois State Geological Survey
121 Natural Resources Building
Urbana, IL 61801
(217) 333-5111

U.S. Soil Conservation Service
State Conservation Office
Federal Building
200 W. Church Street
P.O. Box 678
Champaign, IL 61820
(217) 356-3785

State Agency Contacts and Federal Agency State Offices (cont'd)

U.S. Geological Survey
Water Resources Division
P.O. Box 1026
605 N. Nek Street
Champaign, IL 61820
(217) 398-5353

Indiana

Indiana Department of Natural Resources
Division of Water
608 State Office Building
Indianapolis, IN 46204

Environmental Health
Indiana State Board of Health
1330 W. Michigan Street
Indianapolis, IN 46206

Department of Natural Resources
Indiana Geological Survey
611 North Walnut Grove
Bloomington, IN 47401
(812) 337-2862

U.S. Soil Conservation Service
State Conservation Office
Atkinson Square-West Suite 2200
5610 Crawfordsville Road
Indianapolis, IN 46224
(317) 269-3785

U.S. Geological Survey
Water Resources Division
1819 North Meridan Street
Indianapolis, IN 46202
(317) 269-7101

Iowa

Iowa Natural Resources Council
Wallace State Office Building
East 9th and Grand
Des Moines, IA 50219

Iowa Department of Environmental Quality
Division of Water Supply
Wallance State Office Building
East 9th and Gran
Des Moines, IA 50319

State Agency Contacts and Federal Agency State Offices (cont'd)

Iowa Geological Survey
123 N Capital
Iowa City, IA 52242
(319) 338-1173

U.S. Soil Conservation Service
State Conservation Office
693 Federal Building
210 Walnut Street
Des Moines, IA 50309
(515) 862-4260

U.S. Geological Survey
Water Resources Division
Federal Building - Rm 269
P.O. Box 1230
Iowa City, IA 52244
(319) 337-4191

Kansas

Kansas Oil Field and Environmental Geology
Department of Health and Environment
Topeka, KS 66620

State Geological Survey of Kansas
Raymond C. Moore Hall, University of Kansas
1930 Ave. A, Campus West
Lawrence, KS 66044
(913) 864-3965

U.S. Soil Conservation Service
State Conservation Office
760 South Broadway
P.O. Box 600
Salina, KS 67401
(913) 825-9535

U.S. Geological Survey
Water Resources Division
University of Kansas
1950 Avenue A, Campus West
Lawrence, KS 66045
(913) 864-4321

State Agency Contacts and Federal Agency State Offices (cont'd)

Kentucky

Kentucky Division of Water Resources
Department for Natural Resources and
Environmental Protection
Capital Plaza Tower, Fifth Floor
Frankfort, KY 40601

Kentucky Geological Survey
University of Kentucky
311 Breckinridge Hall
Lexington, KY 40506
(606) 622-3720

U.S. Soil Conservation Service
State Conservation Office
333 Waller Avenue
Lexington, KY 40504
(606) 233-2749 ext. 2749

U.S. Geological Survey
Water Resources Division
Federal Building - Room 572
600 Federal Place
Louisville, KY 40202
(502) 582-5241

Louisiana

Office of Public Works
Louisiana Department of Transportation
and Development
1201 Capital Access Road
Baton Rouge, LA 70804

Louisiana Geological Survey
Box G. University Station
Baton Rouge, LA 70893
(504) 342-6754

U.S. Soil Conservation Service
State Conservation Office
3737 Government Street
P.O. Box 1630
Alexandria, LA 71301
(318) 448-3421

U.S. Geological Survey
Water Resources Division
6554 Florida Boulevard
Baton Rouge, LA 70896
(504) 389-0281

State Agency Contacts and Federal Agency State Offices (cont'd)

Maine

Maine Office of Legislative Assistants
State Capital
Augusta, ME 04333

Maine Geological Survey
State Office Bldg., Room 211
Augusta, ME 04330
(207) 289-2801

U.S. Soil Conservation Service
State Conservation Office
USDA Building
University of Maine
Orono, ME 04473
(207) 866-2132/2133

U.S. Geological Survey
Water Resources Division
(District Office in Mass.)
26 Ganneston Drive
Augusta, ME 04330
(207) 623-4797

Maryland

Division of Water Supply
Maryland Department of Health and Mental Hygiene
201 W. Preston Street
O'Connor Building
Baltimore, MD 21201

Water Resources Administration
Maryland Department of Natural Resources
Tawes State Office Building
580 Taylor Avenue
Annapolis, MD 21401

Maryland Geological Survey
Merryman Hall
Johns Hopkins University
Baltimore, MD 21218
(301) 235-0771

U.S. Soil Conservation Service
State Conservation Office
Room 522, Hartwick Building
4321 Hartwick Road
College Park, MD 20740
(301) 344-4180

State Agency Contacts and Federal Agency State Offices (con'td)

U.S. Geological Survey
Water Resources Division
208 Carroll Building
8600 Lasalle Road
Towson, MD 21204
(301) 828-1535

Massachusetts

Massachusetts Department of Environmental
Management
Water Resources Division
100 Cambridge Street
Boston, MA 02202

Massachusetts Department of Environmental
Management
Water Resources Commission
100 Cambridge Street
Boston, MA 02202

Massachusetts Department of Environmental
Quality Engineering
Division of Waterways - Room 532
100 Nashua Street
Boston, MA 02114
(617) 727-4793

U.S. Soil Conservation Service
State Conservation Office
29 Cottage Street
Amherst, MA 01002
(413) 549-0650

U.S. Geological survey
Water Resources Division
150 Causeway St., Suite 1001
Boston, MA 02114
(617) 223-2822

Michigan

Water Quality Division
Michigan Department of Natural Resources
P.O. Box 30028
Lansing, MI 48909

State Agency Contacts and Federal Agency State Offices (cont'd)

Michigan Department of Natural Resources
Geological Survey Division
P.O. Box 30028
Lansing, MI 48909
(517) 373-1256

Michigan Department of Public Helath
Water Supply Division
3500 N. Logan
P.O. box 30035
Lansing, MI 48909

U.S. Soil Conservation Service
State Conservation Office
1406 South Harrison Road
Room 101
East Lansing, MI 48823
(517) 372-1910 ext. 242

U.S. Geological Survey
Water Resources Division
6520 Mercantile Way - Suite 5
Lansing, MI 48910
(517) 372-1910

Minnesota

Minnesota Department of Natural Resources
Water Division
300 Centennial Building
St. Paul, MN 55155

Minnesota Pollution Control Agency
1935 West Country Road, B-2
Roseville, MN 55113

Minnesota Health Department
717 Delaware Street, N.E.
Minneapolis, MN 55440

Minnesota Geological Survey
1633 Eustis Street
St. Paul, MN 55108
(612) 373-3372

State Agency Contacts and Federal Agency State Offices (cont'd)

U.S. Soil Conservation Service
State Conservation Office
200 Federal Bldg. & U.S. Courthouse
316 North Robert Street
St. Paul, MN 55101
(612) 725-7675

U.S. Geological Survey
Water Resources Division
702 Post Office Building
St. Paul, MN 55101
(612) 725-7841

Mississippi

Bureau of Land and Water Resources
Mississippi Department of Natural Resorces
P.O. Box 10631
Jackson, MS 39209

Mississippi Board of Health
Mississippi Bureau of Environmental Health
Water Supply Division
Jackson, MS 39209

Mississippi Geological, Economic,
and Topological Survey
P.O. Box 4915
Jackson, MS 39216
(601) 354-6228

U.S. Soil Conservation Service
State Conservation Office
Milner Building, Room 590
210 South Lamar Street
P.O. Box 610
Jackson, MS 39205
(601) 969-4330

U.S. Geological Survey
Water Resources Division
Federal Building, Suite 710
100 West Capitol Street
Jackson, MS 39201
(601) 969-4600

State Agency Contacts and Federal Agency State Offices (cont'd)

Missouri

Missouri Department of Natural Resources
Division of Environmental Quality
Water Supply Program
P.O. box 1368
Jefferson City, MO 65102

Missouri State Geological Survey
P.O. Box 250
Rolla, MO 65401
(314) 364-1752

Missouri Department of Natural Resources
Division of Environmental Quality
Public Drinking Water Program
P.O. Box 1368
Jefferson City, MO 65102

U.S. Soil Conservation Service
State Conservation Office
555 Vandiver Drive
Columbia, MO 65201
(314) 442-2271 ext 3155

U.S. Geological Survey
Water Resources Division
Mail Stop 200
1400 Independence Road
Rolla, MO 65401
(314) 341-0824

Montana

Montana Water Rights Bureau
32 South Ewing
Helena, MT 59620

Water Quality Bureau
Montana Department of Health and
Environmental Science
Helena, MT 59601

Montana Bureau of Mines & Geology
Montana College of Mineral Science
and Technology
Butte, MT 59701
(406) 792-8321

State Agency Contacts and Federal Agency State Offices (cont'd)

U.S. Soil Conservation Service
State Conservation Office
Federal Building
P.O. Box 970
Bozeman, MT 59715
(406) 587-5271 ext. 4322

U.S. Geological Survey
Water Resources Division
Federal Building - Drawer 10076
Helena, MT 59601
(406) 559-5263

Nebraska

Nebraska Department of Environmental
Control
301 Centennial Mall South
P.O. Box 94877
Lincoln, NE 68509

Nebraska Department of Water Resources
301 Centennial Mall South
P.O. Box 94676
Lincoln, NE 68509

Conservation & Survey Division
University of Nebraska
Lincoln, NE 68508
(402) 472-3471

U.S. Soil Conservation Service
State Conservation Center
Federal Building
U.S. Courthouse, Room 345
Lincoln, NE 68508
(402) 471-5301

U.S. Geological Survey
Water Resources Division
Federal Building/Courthouse - Room 406
100 Centennial Mall North
Lincoln, NE 68508
(402) 471-5082

State Agency Contacts and Federal Agency State Offices (cont'd)

Nevada

State Engineer
Nevada Department of Conservation and
Natural Resources
201 South Fall Street
Carson City, NV 89710

Nevada Bureau of Mines & Geology
University of Nevada
Reno, NV 89557
(702) 784-6691

U.S. Soil Conservation Service
State Conservation Office
U.S. Post Office Bldg., Rm 308
P.O. Box 4850
Reno, NV 89505
(702) 784-5304

U.S. Geological Survey
Water Resources Division
Federal Building - Room 227
705 North Plaza Street
Carson City, NV 89701
(702) 882-1388

New Hampshire

New Hampshire Office of State Planning
Division of Water Supply
2 1/2 Beacon Street
Concord, NH 03301

Office of State Geologist
James Hall
University of New Hampshire
Durham, NH 03824
(602) 862-1216

U.S. Soil Conservation Service
State Conservation Office
Federal Building
Durham, NH 03824
(603) 868-7581

State Agency Contacts and Federal Agency State Offices (cont'd)

U.S. Geological Survey
Water Resources Division
Subdistrict-Dist. Off./Mass
Federal Bldg. - 210
55 Pleasant Street
Concord, NH 03301
(603) 224-7273

New Jersey

New Jersey Department of Environmental
Protection
Division of Water Resources
P.O. Box CN-029
Trenton, NJ 08625

New Jersey Bureau of Geology
& Topography
P.O. box 1390
Trenton, NJ 08625
(609) 292-2576

U.S. Soil Conservation Service
State Conservation Office
1370 Hamilton Street
P.O. Box 219
Somerset, NJ 08873
(201) 246-1205 ext. 20

U.S. Geological Survey
Water Resources Division
Federal Bldg. Room 436
402 E. State St.
P.O. Box 1238
Trenton, NJ 08607
(609) 989-2162

New Mexico

Water Resources Division
New Mexico Natural Resources Department
Bataan Memorial Building
Santa Fe, NM 87503

Water Pollution Control Bureau
New Mexico Environmental Improvement
Division
P.O. Box 968
Santa Fe, NM 87503

State Agency Contacts and Federal Agency State Offices (cont'd)

New Mexico Interstate Stream commision
Bataan Memorial Building
Santa Fe, NM 87503

New Mexico Bureau of Mines
& Mineral Resources
New Mexico Tech
Socorro, NM 87801
(505) 835-5420

U.S. Soil Conservation Service
State Conservation Office
517 Gold Avenue, SW
P.O. box 2007
Albuquerque, NM 87103
(505) 766-2173

U.S. Geological Survey
Water Resources Division
Western Bank Building
505 Marquette, NW
Albuquerque, NM 87125
(505) 766-2430

New York

New York Department of Environmental
Conservation
Division of Pure Waters
50 Wolf Road
Albany, NY 12233

New York State Geological Survey
State Education Building
Albany, NY 12234
(518) 474-5816

U.S. Soil Conservation Service
State Conservation Office
U.S. Courthouse & Federal Bldg.
100 S. Clinton Street, Room 771
Syracuse, NY 13260
(315) 423-5493

U.S. Geological Survey
Water Resources Division
236 U.S. Post Office/Courthouse
P.O. Box 1350
Albany, NY 12201
(518) 472-3107

State Agency Contacts and Federal Agency State Offices (cont'd)

North Carolina

North Carolina Department of Natural
  Resources and Community Development
Division of Environmental Management
P.O. Box 27687
Raleigh, NC 27611
(919) 733-3833

U.S. Soil Conservation Service
State Conservation Office
310 New Bern Avenue,
Federal Bldg., Room 544
P.O. Box 27307
Raleigh, NC 27611
(919) 755-4165

U.S. Geological Survey
Water Resources Division
Century Station - Room 436
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P.O. Box 2857
Raleigh, NC 27602
(919) 755-4510

North Dakota

North Dakota State Water Commission
900 East Boulevard
Bismarck, ND 58506

Division of Water Supply and
  Pollution Control
North Dakota Department of Health
1200 Missouri Avenue
Bismarck, ND 58505

North Dakota Geological Survey
University Station
Grand Forks, ND 58202
(701) 777-2231

State Agency Contacts and Federal Agency State Offices (cont'd)

U.S. Soil Conservation Service
State Conservation Office
Federal Building - Roser Ave. & 3rd
P.O. Box 1458
Bismarck, ND 58501
(701) 255-4011 ext. 421

U.S. Geological Survey
Water Resources Division
821 E. Interstate Avenue
Bismarck, ND 58501
(701) 255-4011

Ohio

Ohio Department of Natural Resources
Division of Water
Groundwater Section
Fountain Square, Building D
Columbus, OH 43224

Ohio Division of Geological Survey
Fountain Square, Bldg. B
Columbus, OH 43224
(614) 466-5344

U.S. Soil Conservation Service
State Conservation Office
200 No. High St., Room 522
Columbus, OH 43215
(614) 469-6785

U.S. Geological Survey
Water Resources Division
975 West Third Avenue
Columbus, OH 43212
(614) 469-5553

Oklahoma

Chief, Planning and Development Division
Oklahoma Water Resources Board
P.O. Box 53585
N.E. 10th and Stonewall Street
Oklahoma City, OK 78152

Oklahoma Geological Survey
830 Van Vleet Oval, Rm. 163
Norman, OK 73019
(405) 325-3031

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U.S. Soil Conservation Service
State Conservation Office
Agriculture Building
Farm Road & Brumley Street
Stillwater, OK 74074
(405) 624-4360

U.S. Geological Survey
Water Resources Division
215 N.W. 3rd - Room 621
Oklahoma City, OK 73102
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Oregon

Groundwater Section
Oregon Water Resources Department
555 13th Street, N.E.
Salem, OR 97310

Oregon Water Quality Division
P.O. Box 1760
Portland, OR 97207

State Department of Geology and
Mineral Industries
1069 State Office Bldg.
1400 S.W. Fifth Avenue
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(503) 229-5580

U.S. Soil Conservation Service
State Conservation Office
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1220 S.W. 3rd Avenue
Portland, OR 97209
(503) 221-2751

U.S. Geological Survey
Water Resources Division
P.O. Box 3202
830 N.E. Holladay St.
Portland, OR 97208
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Pennsylvania

Pennsylvania Department of Natural Resources
Bureau of Water Quality Management
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Harrisburg, PA 17120

Pennsylvania Bureau of Topography and Geological Survey
Dept. of Environmental Resources
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Harrisburg, PA 17120
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U.S. Soil Conservation Service
State Conservation Office
Federal Bldg. & Courthouse
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Harrisburg, PA 17108
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U.S. Geologial Survey
Water Resources Division
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Harrisburg, PA 17108
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Puerto Rico

Director
Servicio Geologico de P.R.
Dept. of Recursos Naturales
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U.S. Soil Conservation Service
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Puerto Rico, San Juan 00936
Hato Rey, PR 00918
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U.S. Geological Survey
Water Resources Division
Building 652, Ft. Buchanan
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San Juan, PR 00936
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State Agency Contacts and Federal Agency State Offices (cont'd)

Rhode Island

Rhode Island
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Providence, RI 02907

Rhode Island
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Marine Affairs
Graduate School of Oceanography
Kingston, RI 02881

U.S. Soil Conservation Service
State Conservation Office
46 Quaker Lane
West Warwick, RI 02893
(401) 828-1300

U.S. Geological Survey
Water Resources Division
(District Office in Mass.)
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Providence, RI 02903
(401) 528-4655

South Carolina

South Carolina Water Resources Commission
Division of Hydrology
3830 Forest Drive
P.O. Box 4515
Columbia, SC 29240

South Carolina Geological Survey
State Development Board
Harbison Forest Road
Columbia, SC 29210
(803) 758-6431

U.S. Soil Conservation Service
State Conservation Office
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Columbia, SC 29210
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U.S. Geological Survey
Water Resources Division
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1835 Assembly St., Suite 658
Columbia, SC 29201
(803) 765-5966

South Dakota

South Dakota Water and Natural Resources
Joe Foss Building
Pierre, SD 57501

South Dakota State Geological Survey
Science Center
University of South Dakota
Vermillion, SD 57069

U.S. Soil Conservation Service
State Conservation Office
Federal Building, 200 4th St., S.W.
P.O. Box 1357
Huron, SD 57350
(605) 352-8651

Tennessee

Tennessee Department of Public Health
Bureau of Environmental Health
Division of Water Quality Control
Nashville, TN 37220

Tennessee Department of Conservation
Division of Water Resources
4721 Trousdale Avenue
Nashville, TN 37220

Tennessee Department of Conservation
Division of Geology
G-5 State Office Building
Nashville, TN 37219
(615) 741-2726

U.S. Soil Conservation Service
State Conservation Office
675 U.S. Courthouse
Nashville, TN 37203
(615) 749-5471

State Agency Contacts and Federal Agency State Offices (cont'd)

U.S. Geological Survey
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Nashville, TN 37203
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Texas

Texas Department of Water Resources
Box 13087, Capital Station
Austin, TX 78711

Texas Bureau of Economic Geology
University Station, Box X
Austin, TX 78712
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U.S. Soil Conservation Service
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Temple, TX 76501
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U.S. Geological Survey
Water Resources Division
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Austin, TX 78701
(512) 397-5766

Utah

State Engineer
Utah Department of Natural Resources
231 East 400 South
Salt Lake City, UT 84111

Utah Geological & Mineral Survey
606 Black Hawk Way
Salt Lake City, UT 84108
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U.S. Soil Conservation Service
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4012 Federal Bldg.
125 S. State St.
Salt Lake City, UT 84138
(801) 524-5051

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U.S. Geological Survey
Water Resources Division
Administration Bldg. - 1016
1745 West 1700 South
Salt Lake City, UT 84104
(801) 524-5663

Vermont

Vermont Agency of Environmental Conservation
State Office Building
5 Court Street
Montpelier, VT 05602
(802) 828-3357

U.S. Soil Conservation Service
State Conservation Office
1 Burlington Square, Suite 205
Burlington, VT 05401
(802) 862-6501 ext. 6261

U.S. Geological Survey
Water Resources Division
(District Office in Mass.)
U.S. Post Office/Courthouse
Rooms 330B and 330C
Montpelier, VT 05602
(802) 229-4500

Virginia

Virignia State Water Control Board
P.O. Box 11143
2111 Hamilton Street
Richmond, VA 23230

Bureau of Water Supply Engineering
State Health Department
109 Governor's Street
Richmond, VA 23219

Virginia Division of Mineral Resources
P.O. Box 3667
Charlottesville, VA 22903
(804) 293-5121

State Agency Contacts and Federal Agency State Offices (cont'd)

U.S. Soil Conservation Service
State Conservation Office
Federal Bldg, Room 9201
400 N. 8th Street
P.O. Box 10026
Richmond, VA 23240
(804) 782-2457

U.S. Geological Survey
Water Resources Division
200 West Grace St. - Room 304
Richmond, VA 23220
(804) 771-2427

Washington

Washington Department of Ecology
Office of Water Programs
Water Resources Management
Olympia, WA 98504

Washington Dept. of Natural Resources
Geological & Earth Resources Division
Olympia, WA 98504
(206) 753-6183

U.S. Soil Conservation Service
State Conservation Office
360 U.S. Courthouse
W.920 Riverside Avenue
Spokane, WA 99201
(509) 456-3711

U.S. Geological Survey
Water Resources Division
1201 Pacific Ave - Suite 600
Tacoma, WA 98402
(206) 593-6510

West Virginia

West Virginia Department of Natural Resources
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1201 Greenbrier
Charleston, WV 25311

State Agency Contacts and Federal Agency State Offices (cont'd)

West Virginia Geological &
Economic Survey
P.O. Box 879
Morgantown, WV 26505
(304) 292-6331

U.S. Soil Conservation Service
State Conservation Office
75 High Street, P.O. Box 865
Morgantown, WV 26505
(304) 599-7151

U.S. Geological Survey
Water Resources Division
Federal Building/U.S. Courthouse
500 Quarrier St. East-Room 3017
Charleston, WV 25301
(304) 343-6181

Wisconsin

Bureau of Water Mana[illegible]
Wisconsin Department o[illegible]ral Resources
P.O. Box 7921
Madison, WI 53707

Wisconsin Geological & Natural
History Survey
1815 University Ave.
Madison, WI 53706
(608) 262-1705

U.S. Soil Conservation Service
State Conservation Office
4601 Hammersley Road
Madison, WI 53711
(608) 252-5351

U.S. Geological Survey
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Madison, WI 53706
(608) 262-2488

State Agency Contacts and Federal Agency State Offices (cont'd)

Wyoming

Department of Environmental Quality
Water Quality Division
401 West 19th Street
Cheyenne, WY 82002

State Engineer
Barrett Building
Cheyenne, WY 82002

Wyoming Geological Survey
Box 3008, University Station
Laramie, WY 82071
(307) 742-2054

U.S. Soil Conservation Service
State Conservation Office
Federal Office Bldg.
P.O. Box 2440
Casper, WY 82601
(307) 265-5550 ext. 3217

U.S. Geological Survey
Water Resources Division
P.O. box 1125
J C. O'Mahoney Federal Center
2120 Capitol Avenue - Room 5017
Cheyenne, WY 82001
(307) 778-2220

Private Organizations

The Nature Conservancy
National Office Heritage Task Force
1800 North Kent Street
Arlington, VA
(703) 841-5300

National Water Well Association
500 West Wilson Bridge Road
Worthington, OH 43085
(614) 846-9355

APPENDIX C

TABLES OF CHEMICAL-SPECIFIC DATA

Appendix C[1] contains the following six summary data tables:

- Exhibit C-1: Physical, Chemical, and Fate Data
- Exhibit C-2: Half-Lives in Various Media
- Exhibit C-3: Toxicity Data for Potential Carcinogenic Effects -- Selection of Indicator Chemicals Only
- Exhibit C-4: Toxicity Data for Potential Carcinogenic Effects -- Risk Characterization
- Exhibit C-5: Toxicity Data for Noncarcinogenic Effects -- Selection of Indicator Chemicals Only
- Exhibit C-6: Toxicity Data for Noncarcinogenic Effects -- Risk Characterization

These tables summarize key quantitative parameters for more than 300 chemicals or chemical groups that were evaluated as part of the Superfund reportable quantity (RQ) adjustment process or the intra-agency reference dose (RfD) review process. These specific chemicals are included because of the amounts of readily available toxicity information. This list should not be interpreted as a complete list of chemicals of concern for hazardous waste tank systems. Other substances may be important at certain facilities. However, this appendix covers many toxic chemicals commonly stored and treated in hazardous waste tank systems.

Chemical-specific parameters listed in the tables are primarily those referred to in this manual, although a limited amount of other useful information (e.g., CAS number, molecular weight) is also provided. Values for physical, chemical, and fate parameters given in Exhibits C-1 and C-2 are provided for the convenience of the user and have not been fully peer reviewed within EPA. Conversely, values given in Exhibits C-4 and C-6 for acceptable intake level and/or carcinogenic potency have been reviewed within EPA and should generally be used in the health effects evaluation of the risk-based variance to secondary containment of hazardous waste tanks. The sources of values and data transformation procedures, if any, are described in the following sections.

In addition to the six data summary tables described above, a list of chemicals for which EPA Health Effects Assessment documents are available is provided in Exhibit C-7.

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[1] Appendix C is a copy of Appendix C in: EPA, Superfund Public Health Evaluation Manual, Office of Emergency and Remedial Response, October 1986.

C.1 EXHIBIT C-1: PHYSICAL, CHEMICAL, AND FATE DATA

The physical, chemical, and fate data shown in Exhibit C-1 were either recorded directly from standard secondary references or were derived based on information contained in such references. A general hierarchy of sources was established, and values were taken from sources in order of the hierarchy. In general, succeeding references were used only when a value could not be obtained from a reference higher in the hierarchy. Priority was given to more recent sources, and measured values were chosen over estimated values even if obtained from a source lower on the hierarchy. The hierarchy of sources used to select values for Exhibit C-1 is shown below and is lettered to correspond with the sources referenced in the exhibit. More complete reference information for each of these sources is in the reference list for Appendix C. A brief description of the derivation of values for each parameter in Exhibit C-1 follows the hierarchy listed below.

A) ECAO, EPA, Health Effects Assessments, 1985
B) Jaber *et al*., 1984
C) Mabey *et al*., 1982
D) Callahan *et al*., 1979
E) ORD, EPA, 1981
F) Dawson *et al*., 1980
G) Lyman *et al*., 1982
H) OWRS, EPA, 1980
I) Weast *et al*., 1979
J) Verschueren, 1983
K) Windholz *et al*., 1976
L) Perry and Chilton, 1973
M) OSW, EPA, 1984b
N) OSW, EPA, 1984a

Water Solubility is the maximum concentration of a chemical that dissolves in pure water at a specific temperature and pH. It is a critical property affecting environmental fate and transport. Values for water solubility, in mg/l, were recorded in Exhibit C-1 directly using the hierarchy of sources and general decision rules outlined above. Values are given for a neutral pH and a temperature range of 20 to 30°C. Chemicals listed in the literature as being "infinitely soluble" were assigned a solubility value of 1,000,000 mg/l.

Vapor Pressure is a relative measure of the volatility of a chemical in its pure state and is an important determinant of its rate of vaporization. Values for this parameter, in units mm Hg, were recorded directly from the hierarchy of sources listed above. Values are given for a temperature range of 20 to 30° C.

Henry's Law Constant is another parameter important in evaluating air exposure pathways. Values for Henry's Law Constant (H) were calculated using the following equation and the values previously recorded for solubility, vapor pressure, and molecular weight:

$$H(\text{atm-m}^3/\text{mole}) = \frac{\text{Vapor Pressure (atm)} \times \text{Mole Weight (g/mole)}}{\text{Water Solubility (g/m}^3\text{)}}$$

Organic Carbon Partition Coefficient (Koc) is a measure of the tendency for organics to be adsorbed by soil and sediment and is expressed as:

$$\text{Koc} = \frac{\text{mg chemical adsorbed/kg organic carbon}}{\text{mg chemical dissolved/liter of solution}}$$

The Koc is chemical specific and is largely independent of soil properties. Most Koc values in Exhibit C-1 were recorded directly from the above hierarchy of sources. However, some Koc values were estimated using methods specified in Lyman (1982). Estimated values are clearly designated as such.

Octanol-Water Partition Coefficient (Kow) is a measure of how a chemical is distributed at equilibrium between octanol and water, and is used often in the assessment of environmental fate and transport for organic chemicals. Additionally, Kow is a key variable used in the estimation of other properties. For the convenience of the user, values for log Kow have been included in Exhibit C-1. These values were recorded directly from the hierarchy of sources referenced above.

Bioconcentration Factor as used in this manual is a measure of the tendency for a chemical contaminant in water to accumulate in fish tissue. The equilibrium concentration of a contaminant in fish can be estimated by multiplying the concentration of the chemical in surface water by the fish bioconcentration factor for that chemical. This parameter is therefore an important determinant for human intakes via the aquatic food ingestion route. Values for bioconcentration factors shown in Exhibit C-1 were recorded directly from the above hierarchy of sources.

C.2 EXHIBIT C-2: HALF-LIVES IN VARIOUS MEDIA

Chemical Half-Lives are used in this manual as measures of persistence, or how long a chemical will remain, in various environmental media. Exhibit C-2 presents values for overall half-lives, which are the result of all removal processes (e.g., phase transfer, chemical transformation, and biological transformation) acting together rather than a single removal mechanism. All of the half-life values in Exhibit C-2 were recorded directly from two sources, ECAO Health Effects Assessments (ECAO, 1985) and exposure profiles for the RCRA Risk-Cost Analysis Model (OSW, 1984b). The same source lettering convention was followed for Exhibit C-2 as for Exhibit C-1.

C.3 EXHIBIT C-3: TOXICITY DATA FOR POTENTIAL CARCINOGENIC EFFECTS -- SELECTION OF INDICATOR CHEMICALS ONLY

For the risk assessment process outlined in this manual, data presented in Exhibit C-3 are used only in the selection of indicator chemicals and not in actual risk characterization. These data were obtained from information contained in the Reportable Quantity (RQ) data base (OHEA, 1986). The procedures used to convert source data to the values given in Exhibit C-3 are described briefly below.

The 10% Effective Dose (ED_{10}) represents the dose at which a 10 percent incremental carcinogenic response is observed. This parameter was calculated for both oral and inhalation routes by taking the reciprocal of the Potency Factor Estimate (PFE) given in the RQ data base (this source defines PFE = $1/ED_{10}$; therefore, $ED_{10} = 1/PFE$). The ED_{10} is in units of mg/kg/day.

Toxicity Constants vary for different exposure media. As such, Exhibit C-3 contains toxicity constant values specific to water (wTc) and soil (sTc) for the oral route, and a value for air (aTc) for the inhalation route. Each of these constants for potential carcinogens is based on the ED_{10}, standard intake assumptions for the respective media, and a standard body weight. The specific equations and assumptions used to calculate the various toxicity constants are presented and discussed in further detail in Appendix D.

C.4 EXHIBIT C-4: TOXICITY DATA FOR POTENTIAL CARCINOGENIC EFFECTS -- RISK CHARACTERIZATION

Data presented in Exhibit C-4 are for use in risk characterization, as opposed to the selection of indicator chemicals. Values in this exhibit were derived in the following manner.

Carcinogenic Potency Factors are upper 95 percent confidence limits on the slope of the dose-response curve. These values were recorded directly from HEAs or CAG summary tables, with the actual source cited in the exhibit for each value and then fully referenced at the end of the exhibit. Potency factors are used to estimate potential carcinogenic risk. These factors, specific to different exposure routes, are given in Exhibit C-4 in units of $(mg/kg/day)^{-1}$.

Weight of Evidence ratings qualify the level of evidence that supports designating a chemical as a human carcinogen. Exhibit C-4 lists ratings based on EPA categories for potential carcinogens, which are fully itemized in Exhibit D-2. The ratings were recorded directly from the RQ data base. (Note: Weight-of-evidence ratings are also used in the procedure for selecting indicator chemicals.)

C.5 EXHIBIT C-5: TOXICITY DATA FOR NONCARCINOGENIC EFFECTS -- SELECTION OF INDICATOR CHEMICALS ONLY

The data in Exhibit C-5 were generated based on information contained in the RQ data base for chronic effects (ECAO, 1984). Values for the parameters in Exhibit C-5, which are used in the selection of indicator chemicals but not in risk characterization, were derived in the following manner. In addition, chemicals marked in Exhibit C-5 with "@" also exhibit potential carcinogenic effects. The reader is referred to Exhibits C-3 and C-4 for information concerning these effects.

To determine the human Minimum Effective Dose (MED), the RQ data base was reviewed to identify the studies with the highest composite score (a score that combines MED and severity of effect) for oral and for inhalation exposure routes. These MEDs were recorded under the appropriate exposure route in Exhibit C-5. If composite score values were reported to be equal, the study that yielded the lowest MED was used. For metals, one MED value was derived from all studies for the various compounds of a given metal. Human MED values are expressed in Exhibit C-5 in terms of mg/day. If an MED was available for only one exposure route, it was recorded in Exhibit C-5 for the other exposure routes without modification unless the toxic effect was at the site of entry.

Severity of Effect Ratings, or RVe's, were recorded from the RQ data base for the same study used to determine MED values. These rating constants are unitless integers ranging from 1 to 10, corresponding to various levels of severity of effects. The severity scale is presented in Exhibit D-1.

Toxicity Constants for noncarcinogenic effects, like those for carcinogens, are specific to water, soil, and air and are designated in Exhibit C-5 as wTn, sTn, and aTn, respectively. Again, these toxicity constants are used only in the indicator chemical selection step of the process. Values in Exhibit C-5 are based on standard intake assumptions as well as a chemical's RVe and MED values. Refer to Appendix D for the specific toxicity constant equations and for a discussion on their application.

C.6 EXHIBIT C-6: TOXICITY DATA FOR NONCARCINOGENIC EFFECTS -- RISK CHARACTERIZATION

Exhibit C-6 gives values for parameters that are used in actual risk characterization. The methods used to derive these values are described below. Although the data in Exhibit C-6 are for noncarcinogenic effects, several of the chemicals listed in the exhibit (those marked with an "@") also exhibit potential carcinogenic effects. Exhibits C-3 and C-4 should be referred to for information concerning carcinogenic effects.

Subchronic acceptable intake (AIS) values are short-term acceptable intake levels and are recorded directly from the appropriate HEA. Likewise, values for chronic acceptable intake (AIC), which is the long-term acceptable intake level for noncarcinogenic effects, were recorded directly from the appropriate HEA or from compilations of Agency-verified reference dose (RfD) values. These verified reference doses were developed by an EPA work group chaired by the Office of Research and Development in 1985 and 1986. The actual source used for each value is cited in Exhibit C-6 and is referenced fully at the end of the exhibit. AIS and AIC are used to characterize risks of noncarcinogenic effects. Both AIS and AIC values are in units of mg/kg/day.

REFERENCES FOR APPENDIX C

CAG, U.S. EPA, 1985. Relative Carcinogenic Potencies Among 54 Chemicals Evaluated by the Carcinogen Assessment Group As Suspect Human Carcinogens.

Callahan *et al*., 1979. Water-Related Environmental Fate of 129 Priority Pollutants, Volumes I and II, Office of Water Planning and Standards, Office of Water and Waste Management, U.S. EPA, EPA Contract Nos. 68-01-3852 and 68-01-3867. [Source D*]

Dawson, *et al*., 1980. Physical/Chemical Properties of Hazardous Waste Constituents. Prepared By Southeast Environmnetal Research Laboratory for U.S. EPA. [Source F*]

ECAO, U.S. EPA, 1985. Health Effects Assessment for [Specific Chemical]. [Note: 58 individual documents available for specific chemicals or chemical groups] [Source A*]

ECAO, U.S. EPA, 1984. Summary Data Tables for Chronic Noncarcinogenic Effects. [Note: Prepared during RQ adjustment process]

Jaber, *et al*., 1984. Data Acquisition for Environmental Transport and Fate Screening. Office of Health and Environmental Assessment, U.S. EPA, Washington, DC, EPA 600/6-84-009 [Source B*]

Lyman, 1982. Adsorption Coefficient for Soils and Sediments. Chapter 4 in Lyman *et al*., *Handbook of Chemical Property Estimation Methods*. McGraw-Hill, New York.

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Mabey, *et al*., 1982. Aquatic Fate Process Data for Organic Priority Pollutants. Prepared by SRI International, EPA Contract Nos. 68-01-3867 and 68-03-2981, prepared for Monitoring and Data Support Division, Office of Water Regulations and Standards, Washington, DC. [Source C*]

OHEA, U.S. EPA, 1986. Methodology for Evaluating Reportable Quantity Adjustments Pursuant to CERCLA Section 102, External Review Draft. OHEA-C-073.

ORD, U.S. EPA, 1981. Treatability Manual, Volume I, EPA 600/2-82-001a. [Source E*]

OSW, U.S. EPA, 1984a. Characterization of Constituents from Selected Waste Streams Listed in 40 CFR Section 261. Prepared by Environ Corporation. [Source N*]

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*Source letters correspond to Exhibits C-1 and C-2.

OSW, U.S. EPA, 1984b. Exposure Profiles for RCRA Risk-Cost Analysis Model. Prepared by Environ Corporation. [Source M*]

OWRS, U.S. EPA, 1980. Ambient Water Quality Criteria Documents for [Specific Chemical]. [Source H*]

Perry and Chilton, 1973. Chemical Engineers' Handbook, McGraw-Hill, 5th Ed. [Source L*]

Verschueren, 1983. Handbook of Environmental Data for Organic Chemicals. Van Nostrand Reinhold Co., New York, 2nd ed. [Source J*]

Weast *et al*., 1979. CRC Handbook of Chemistry and Physics. [Source I*]

Windholz, *et al*., 1976. The Merck Index. [Source K*]

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*Source letters correspond to Exhibits C-1 and C-2.

Date Prepared: October 1, 1986

EXHIBIT C-1

PHYSICAL, CHEMICAL, AND FATE DATA

Chemical Name	CAS #	Mole Weight (g/mole)	Water Solubility (mg/l)	S*	Vapor Pressure (mm Hg)	S*	Henry's Law Constant (atm-m3/mol)	Koc (ml/g)	S*	Log Kow	S*	Fish BCF (l/kg)	S*
Acenaphthene	83-32-9	154	3.42E+00	C	1.55E-03	C	9.20E-05	4600	C	4.00	C	242	H
Acenaphthylene	208-96-8	152	3.93E+00	C	2.90E-02	C	1.48E-03	2500	C	3.70	C		
Acetone	67-64-1	58	1.00E+06	#	2.70E+02	J	2.06E-05	2.2	&	-0.24	J		
Acetonitrile	75-05-8	41	1.00E+06	#	7.40E+01	F	4.00E-06	2.2	&	-0.34	I		
2-Acotylaminofluorene	53-96-3	223	6.50E+00	B			NA	1600	&	3.28	B		
Acrylic Acid	79-10-7	72	1.00E+06	#	4.00E+00	F				0.13	I	0	F
Acrylonitrile	107-13-1	53	7.90E+04	C	1.00E+02	C	8.84E-05	0.85	C	0.25	C	48	G
Aflatoxin B1	1162-65-8	312					NA						
Aldicarb	116-06-3	190											
Aldrin	309-00-2	365	1.80E-01	C	6.00E-06	C	1.60E-05	96000	C	5.30	C	28	H
Allyl Alcohol	107-18-6	58	5.10E+05	B	2.46E+01	B	3.69E-06	3.2	&	-0.22	B		
Aluminum Phosphide	20859-73-8	58											
4-Aminobiphenyl	92-67-1	169	8.42E+02	B	6.00E-05	B	1.59E-08	107	&	2.78	B		
Amitrole	61-82-5	84	2.80E+05	B			NA	4.4	&	-2.08	B		
Ammonia	7664-41-7	17	5.30E+05	F	7.60E+03	F	3.21E-04	3.1	&	0.00	F	0	F
Anthracene	120-12-7	178	4.50E-02	A	1.95E-04	A	1.02E-03	14000	C	4.45	A		
Antimony and Compounds	7440-36-0	122			1.00E+00	N	NA					1	H
Arsenic and Compounds	7440-38-2	75			0.00E+00	E	NA					44	H
Asbestos	1332-21-4	NA	NA		NA		NA	NA		NA		0	D
Auramine	2465-27-2	267	2.10E+00	B			NA	2900	&	4.16	B		
Azaserine	115-02-6	173	1.36E+05	B			NA	6.6	&	-1.08	B		
Aziridine	151-56-4	43	2.66E+06	B	2.55E+02	B	5.43E-06	1.3	&	-1.01			
Barium and Compounds	7440-39-3	137					NA						
Benefin	1861-40-1	335											
Benzene	71-43-2	78	1.75E+03	A	9.52E+01	A	5.59E-03	83	G	2.12	A	5.2	H
Benzidine	92-87-5	184	4.00E+02	C	5.00E-04	C	3.03E-07	10.5	C	1.30	C	87.5	H
Benz(a)anthracene	56-55-3	228	5.70E-03	C	2.20E-08	C	1.16E-06	1380000	G	5.60	C		
Benz(c)acridine	225-51-4	229	1.40E+01	B			NA	1000	&	4.56	B		
Benzo(a)pyrene	50-32-8	252	1.20E-03	A	5.60E-09	A	1.55E-06	5500000	C	6.06	C		
Benzo(b)fluoranthene	205-99-2	252	1.40E-02	C	5.00E-07	C	1.19E-05	550000	C	6.06	A		
Benzo(ghi)perylene	191-24-2	276	7.00E-04	A	1.03E-10	A	5.34E-08	1600000	C	6.51	A		
Benzo(k)fluoranthene	207-08-9	252	4.30E-03	C	5.10E-07	C	3.94E-05	550000	C	6.06	C		
Benzotrichloride	98-07-7	195											
Benzyl Chloride	100-44-7	127	3.30E+03	F	1.00E+00	E	5.06E-05	50	&	2.63	F		
Beryllium and Compounds	7440-41-7	9			0.00E+00	E	NA					19	H
1,1-Biphenyl	92-52-4	154											
Bis(2-chloroethyl)ether	111-44-4	143	1.02E+04	C	7.10E-01	C	1.31E-05	13.9	C	1.50	C	6.9	H
Bis(2-chloroisopropyl)ether	108-60-1	171	1.70E+03	C	8.50E-01	C	1.13E-04	61	C	2.10	C	0	D
Bis(chloromethyl)ether	542-88-1	115	2.20E+04	C	3.00E+01	C	2.06E-04	1.2	C	0.38	C	0.63	H
Bis(2-ethylhexyl)phthalate (DEHP)	117-81-7	391											
Bromomethane	74-83-9	95											
Bromoxynil Octanoate	1689-99-2	403											
1,3-Butadiene	106-99-0	54	7.35E+02	F	1.84E+03	F	1.78E-01	120	&	1.99	F		
n-Butanol	71-36-3	74											
Butylphthalyl Butylglycolate	85-70-1	336											
Cacodylic Acid	75-60-5	138	8.30E+05	F			NA	2.4	&	0.00	I		
Cadmium and Compounds	7440-43-9	112			0.00E+00	E	NA					81	H
Captan	133-06-2	301	5.00E-01	E	6.00E-05	E	4.75E-05	6400	&	2.35	I		
Carbaryl	63-25-2	201	4.00E+01	E	5.00E-03	E				2.36	I		
Carbon Disulfide	75-15-0	76	2.94E+03	E	3.60E+02	E	1.23E-02	54	&	2.00	I	0	F
Carbon Tetrachloride	56-23-5	154	7.57E+02	A	9.00E+01	A	2.41E-02	110	&	2.64	A	19	H
Chlordane	57-74-9	410	5.60E-01	A	1.00E-05	A	9.63E-06	140000	C	3.32	A	14000	H
Chlorobenzene	108-90-7	113	4.66E+02	A	1.17E+01	A	3.72E-03	330	C	2.84	A	10	H
Chlorobenzilate	510-15-6	325	2.19E+01	B	1.20E-06	B	2.34E-08	800	&	4.51	B		
Chlorodibromomethane	124-48-1	208			1.50E+01	D	NA			2.09	B		

Date Prepared: October 1, 1986

EXHIBIT C-1
(Continued)

PHYSICAL, CHEMICAL, AND FATE DATA

Chemical Name	CAS #	Mole Weight (g/mole)	Water Solubility (mg/l)	S*	Vapor Pressure (mm Hg)	S*	Henry's Law Constant (atm-m3/mol)	Koc (ml/g)	S*	Log Kow	S*	Fish BCF (l/kg)	S*
Chloroform	67-66-3	119	8.20E+03	A	1.51E+02	A	2.87E-03	31	&	1.97	A	3.75	H
Chloromethyl Methyl Ether	107-30-2	81					NA			0.00	F		
4-Chloro-o-toluidine Hydrochloride	3165-93-3	142					NA						
Chromium III and Compounds	7440-47-3	52			0.00E+00	E	NA					16	H
Chromium VI and Compounds	7440-47-3	52			0.00E+00	E	NA					16	H
Chrysene	218-01-9	228	1.80E-03	A	6.30E-09	A	1.05E-06	200000	C	5.61	A		
Copper and Compounds	7440-50-8	64			0.00E+00	G	NA					200	D
Creosote	8001-58-9	NA					NA						
Cresol	1319-77-3	108	3.10E+04	E	2.40E-01	J	1.10E-06	500	G	1.97	F	0	F
Crotonaldehyde	123-73-9	70											
Cyanides	57-12-5	NA					NA						
-- Barium Cyanide	542-62-1	189											
-- Calcium Cyanide	592-01-8	92											
-- Copper Cyanide	544-92-3	90											
-- Cyanogen	460-19-5	52	2.50E+05	K									
-- Cyanogen Chloride	506-77-4	61	2.50E+03	F	1.00E+03	J				0.00	I		
-- Hydrogen Cyanide	74-90-8	27	1.00E+06	#	6.20E+02	E				-0.25	I	0	F
-- Nickel Cyanide	557-19-7	182											
-- Potassium Cyanide	151-50-8	65	5.00E+05	K									
-- Potassium Silver Cyanide	506-61-6	199											
-- Silver Cyanide	506-64-9	134											
-- Sodium Cyanide	143-33-9	49	8.20E+05	H									
-- Zinc Cyanide	557-21-1	117											
Cyclophosphamide	50-18-0	261	1.31E+09	B			NA	0.042	&	-3.22	B		
Dalapon	75-99-0	143											
DDD	72-54-8	320	1.00E-01	C	1.89E-06	C	7.96E-06	770000	C	6.20	C		
DDE	72-55-9	318	4.00E-02	C	6.50E-06	C	6.80E-05	4400000	C	7.00	C	51000	G
DDT	50-29-3	355	5.00E-03	A	5.50E-06	A	5.13E-04	243000	G	6.19	J	54000	H
Decabromodiphenyl Ether	1163-19-5	959											
Diallate	2303-16-4	274	1.40E+01	B	6.40E-03	B	1.65E-04	1000	&	0.73	B		
2,4-Diaminotoluene	95-80-7	122	4.77E+04	B	3.80E-05	B	1.28E-10	12	&	0.35	B		
1,2,7,8-Dibenzopyrene	189-55-9	305	1.10E-01	B			NA	1200	&	6.62	B		
Dibenz(a,h)anthracene	53-70-3	278	5.00E-04	C	1.00E-10	C	7.33E-08	3300000	C	6.80	C		
1,2-Dibromo-3-chloropropane	96-12-8	236	1.00E+03	B	1.00E+00	B	3.11E-04	98	&	2.29	B		
Dibutylnitrosamine	924-16-3	152					NA						
Dibutyl Phthalate	84-74-2	278	1.30E+01	C	1.00E-05	C	2.82E-07	170000	C	5.60	C		
1,2-Dichlorobenzene	95-50-1	147	1.00E+02	C	1.00E+00	C	1.93E-03	1700	C	3.60	C	56	H
1,3-Dichlorobenzene	541-73-1	147	1.23E+02	C	2.28E+00	C	3.59E-03	1700	C	3.60	C	56	H
1,4-Dichlorobenzene	106-46-7	147	7.90E+01	C	1.18E+00	C	2.89E-03	1700	C	3.60	C	56	H
3,3'-Dichlorobenzidine	91-94-1	253	4.00E+00	C	1.00E-05	C	8.33E-07	1553	C	3.50	C	312	H
Dichlorodifluoromethane	75-71-8	121	2.80E+02	C	4.87E+03			58	C	2.16	D		
1,1-Dichloroethane	75-34-3	99	5.50E+03	A	1.82E+02	A	4.31E-03	30	C	1.79	A		
1,2-Dichloroethane (EDC)	107-06-2	99	8.52E+03	A	6.40E+01	A	9.78E-04	14	C	1.48	A	1.2	H
1,1-Dichloroethylene	75-35-4	97	2.25E+03	A	6.00E+02	A	3.40E-02	65	C	1.84	A	5.6	H
1,2-Dichloroethylene (trans)	540-59-0	97	6.30E+03	A	3.24E+02	A	6.56E-03	59	C	0.48	A	1.6	H
1,2-Dichloroethylene (cis)	540-59-0	97	3.50E+03	A	2.08E+02	A	7.58E-03	49	&	0.70	A	1.6	H
Dichloromethane	75-09-2	85	2.00E+04	C	3.62E+02	C	2.03E-03	8.8	C	1.30	C	5	H
2,4-Dichlorophenol	120-83-2	163	4.60E+03	C	5.90E-02	C	2.75E-06	380	C	2.90	C	41	H
2,4-Dichlorophenoxyacetic Acid (2,4-D)	94-75-7	221	6.20E+02	F	4.00E-01	F	1.88E-04	20	G	2.81	I		
4-(2,4-Dichlorophenoxy)butyric Acid (2,4-DB)	94-82-6												
Dichlorophenylarsine	696-28-6	223					NA						
1,2-Dichloropropane	78-87-5	113	2.70E+03	C	4.20E+01	C	2.31E-03	51	C	2.00	C		

Date Prepared: October 1, 1986

EXHIBIT C-1
(Continued)

PHYSICAL, CHEMICAL, AND FATE DATA

Chemical Name	CAS #	Mole Weight (g/mole)	Water Solubility (mg/l)	S*	Vapor Pressure (mm Hg)	S*	Henry's Law Constant (atm-m3/mol)	Koc (ml/g)	S*	Log Kow	S*	Fish BCF (l/kg)	S*
1,3-Dichloropropene	542-75-6	111	2.80E+03	C	2.50E+01	C	1.30E-03	48	C	2.00	C	1.9	H
Dieldrin	60-57-1	381	1.95E-01	C	1.78E-07	C	4.58E-07	1700	C	3.50	C	4760	H
Diepoxybutane	1464-53-5	86					NA						
Diethanolnitrosamine	1116-54-7	134					NA						
Diethyl Arsine	692-42-2	134	4.17E+02	B	3.50E+01	B	1.48E-02	160	&	2.97	B		
1,2-Diethylhydrazine	1615-80-1	88	2.88E+07	B			NA	0.3	&	-1.68	B		
Diethylnitrosamine	55-18-5	102			5.00E+00	F	NA			0.48	I		
Diethyl Phthalate	84-66-2	222	8.96E+02	C	3.50E-03	C	1.14E-06	142	C	2.50	C	117	G
Diethylstilbestrol (DES)	56-53-1	268	9.60E-03	B			NA	28	&	5.46	B		
Dihydrosafrole	94-58-6	164	1.50E+03	B			NA	78	&	2.56	B		
Dimethoate	60-51-5	229	2.50E+04	J	2.50E-02	J				2.71	J		
3,3'-Dimethoxybenzidine	119-90-4	244					NA						
Dimethylamine	124-40-3	45	1.00E+06	F	1.52E+03	F	9.02E-05	2.2	&	-0.38	I	0	F
Dimethyl Sulfate	77-78-1	126	3.24E+05	B	6.80E-01	B	3.48E-07	4.1	&	-1.24	B		
Dimethyl Terephthalate	120-61-6	194											
Dimethylaminoazobenzene	60-11-7	225	1.36E+01	B	3.30E-07	B	7.19E-09	1000	&	3.72	B		
7,12-Dimethylbenz(a)anthracene	57-97-6	256	4.40E-03	B			NA	476000	G	6.94	B		
3,3'-Dimethylbenzidine	119-93-7	212											
Dimethylcarbamoyl Chloride	79-44-7	108	1.44E+07	B	1.95E+00	B	1.92E-08	0.5	&	-1.32	B		
1,1-Dimethylhydrazine	57-14-7	60	1.24E+08	B	1.57E+02	B	1.00E-07	0.2	&	-2.42	B		
1,2-Dimethylhydrazine	540-73-8	60					NA						
Dimethylnitrosamine	62-75-9	74	1.00E+06	#	8.10E+00	C	7.90E-07	0.1	C	-0.68	C	0	D
1,3-Dinitrobenzene	99-65-0	168	4.70E+02	J			NA	150	&	1.62	I		
4,6-Dinitro-o-cresol	534-52-1	198	2.90E+02	C	5.00E-02	C	4.49E-05	240	C	2.70	C	0	E
2,4-Dinitrophenol	51-28-5	184	5.60E+03	C	1.49E-05	C	6.45E-10	16.6	C	1.50	C	0	D
2,3-Dinitrotoluene	602-01-7	182	3.10E+03	B			NA	53	&	2.29	B	3.8	H
2,4-Dinitrotoluene	121-14-2	182	2.40E+02	C	5.10E-03	C	5.09E-06	45	C	2.00	C	3.8	H
2,5-Dinitrotoluene	619-15-8	182	1.32E+03	B			NA	84	&	2.28	B	3.8	H
2,6-Dinitrotoluene	606-20-2	182	1.32E+03	B	1.80E-02	C	3.27E-06	92	C	2.00	C	3.8	H
3,4-Dinitrotoluene	610-39-9	182	1.08E+03	B			NA	94	&	2.29	B	3.8	H
Dinoseb	88-85-7	240	5.00E+01	J									
1,4-Dioxane	123-91-1	88	4.31E+05	B	3.99E+01	B	1.07E-05	3.5	&	0.01	B		
N,N-Diphenylamine	122-39-4	169	5.76E+01	B	3.80E-05	B	1.47E-07	470	&	3.60	B	30	G
1,2-Diphenylhydrazine	122-66-7	184	1.84E+03	C	2.60E-05	C	3.42E-09	418	C	2.90	C	25	H
Dipropylnitrosamine	621-64-7	130	9.90E+03	C	4.00E-01	C	6.92E-06	15	C	1.50	C		
Disulfoton	298-04-4	274											
Endosulfan	115-29-7	407											
Epichlorohydrin	106-89-8	93	6.00E+04	J	1.57E+01	B	3.19E-05	10	&	0.15	B		
Ethanol	64-17-5	46	1.00E+06	#	7.40E+02	G	4.48E-05	2.2	&	-0.32	J		
Ethyl Acetate	141-78-6	88											
Ethyl Methanesulfonate	62-50-0	124	3.69E+05	B	2.06E-01	B	9.12E-08	3.8	&	0.21	B		
Ethylbenzene	100-41-4	106	1.52E+02	A	7.00E+00	A	6.43E-03	1100	C	3.15	A	37.5	H
Ethyl-4,4'-dichlorobenzilate	510-15-6	352											
Ethylene Dibromide (EDB)	106-93-4	188	4.30E+03	J	1.17E+01	B	6.73E-04	44	G	1.76	B		
Ethylene Oxide	75-21-8	44	1.00E+06	B	1.31E+03	B	7.56E-05	2.2	&	-0.22	B		
Ethylenethiourea	96-45-7	102	2.00E+03	F			NA	67	&	-0.66	J	0	F
1-Ethyl-nitrosourea	759-73-9	117	3.31E+08	B			NA	0.1	&				
Ethylphthalyl Ethyl Glycolate	84-72-0	280											
Ferric Dextran	9004-66-4	7500					NA						
Fluoranthene	206-44-0	202	2.06E-01	A	5.00E-06	A	6.46E-06	38000	C	4.90	A	1150	H
Fluorene	86-73-7	116	1.69E+00	C	7.10E-04	C	6.42E-05	7300	C	4.20	C	1300	G
Fluorides	7782-41-4	NA					NA						
Fluridone	59756-60-4	329											
Formaldehyde	50-00-0	30	4.00E+05	K	1.00E+01	I	9.87E-07	3.6	&	0.00	I	0	F

Date Prepared: October 1, 1986

EXHIBIT C-1
(Continued)

PHYSICAL, CHEMICAL, AND FATE DATA

Chemical Name	CAS #	Mole Weight (g/mole)	Water Solubility (mg/l)	S*	Vapor Pressure (mm Hg)	S*	Henry's Law Constant (atm-m3/mol)	Koc (ml/g)	S*	Log Kow	S*	Fish BCF (l/kg)	S*
Formic Acid	64-18-6	46	1.00E+06		4.00E+01	E				-0.54	I	0	F
Furan	110-00-9	68											
Glycidaldehyde	765-34-4	72	1.70E+08	B	1.97E+01	B	1.10E-08	0.1	&	-1.55	B		
Glycol Ethers	NA	NA					NA						
-- Diethylene Glycol, Monoethyl Ether	111-90-0	134											
-- 2-Ethoxyethanol	110-80-5	90	1.00E+06	F						0.00	I		
-- Ethylene Glycol, Monobutyl Ether	111-76-2	118	1.00E+06	F						0.00	I		
-- 2-Methoxyethanol	109-86-4	76	1.00E+06	K									
-- Propylene Glycol, Monoethyl Ether	52125-53-8	104											
-- Propylene Glycol, Monomethyl Ether	107-98-2	90											
Heptachlor	76-44-8	374	1.80E-01	C	3.00E-04	C	8.19E-04	12000	C	4.40	C	15700	H
Heptachlor Epoxide	1024-57-3	389	3.50E-01	C	3.00E-04	C	4.39E-04	220	C	2.70	C	14400	G
Hexachlorobenzene	118-74-1	285	6.00E-03	A	1.09E-05	A	6.81E-04	3900	G	5.23	A	8690	H
Hexachlorobutadiene	87-68-3	261	1.50E-01	A	2.00E+00	A	4.57E+00	29000	C	4.78	A	2.8	H
Hexachlorocyclopentadiene	77-47-4	273	2.10E+00	A	8.00E-02	A	1.37E-02	4800	C	5.04	A	4.3	H
alpha-Hexachlorocyclohexane (HCCH)	319-84-6	291	1.63E+00	C	2.50E-05	C	5.87E-06	3800	C	3.90	C	130	H
beta-HCCH	319-85-7	291	2.40E-01	C	2.80E-07	C	4.47E-07	3800	C	3.90	C	130	H
gamma-HCCH (Lindane)	58-89-9	291	7.80E+00	C	1.60E-04	C	7.85E-06	1080	G	3.90	C	130	H
delta-HCCH	319-86-8	291	3.14E+01	C	1.70E-05	C	2.07E-07	6600	C	4.10	C	130	H
Hexachloroethane	67-72-1	237	5.00E+01	C	4.00E-01	C	2.49E-03	20000	C	4.60	C	87	H
Hexachlorophene	70-30-4	407	4.00E-03	F			NA	91000	&	7.54	F		
Hydrazine	302-01-1	32	3.41E+08	B	1.40E+01	B	1.73E-09	0.1	&	-3.08	B		
Hydrogen Sulfide	7783-06-4	34	4.13E+03	K									
Indeno(1,2,3-cd)pyrene	193-39-5	276	5.30E-04	C	1.00E-10	C	6.86E-08	1600000	C	6.50	C		
Iodomethane	77-88-4	142	1.40E+04	J	4.00E+02	J	5.34E-03	23	&	1.69	J		
Iron and Compounds	15438-31-0	56					NA						
Isobutanol	78-83-1	74											
Isoprene	78-79-5	68			4.00E+02	E	NA						
Isosafrole	120-58-1	168	1.09E+03	B	1.60E-08	B	3.25E-12	93	&	2.66	B		
Isophorone	78-59-1	138											
Isopropalin	33820-53-0	309											
Kepone	143-50-0	491	9.90E-03	B			NA	55000	&	2.00	B	8400	G
Lasiocarpine	303-34-4	412	1.60E+03	B			NA	76	&	0.99	B		
Lead and Compounds (Inorganic)	7439-92-1	207			0.00E+00	E	NA					49	H
Linuron	330-55-2	249											
Malathion	121-75-7	330	1.45E+02	E	4.00E-05	E				2.89	J	0	F
Manganese and Compounds	7439-96-5	55					NA						
Melphalan	148-82-3	305											
Mercury and Compounds (Alkyl)	7439-97-6						NA					3750	H
Mercury and Compounds (Inorganic)	7439-97-6	201			2.00E-03	F	NA					5500	H
Mercury Fulminate	628-86-4	285											
Methanol	67-56-1	32											
Methyl Chloride	74-87-3	50	6.50E+03	C	4.31E+03	B	4.40E-02	35	&	0.95	B		
Methyl Ethyl Ketone	78-93-3	72	2.68E+05	A	7.75E+01	A	2.74E-05	4.5	&	0.26	A	0	F
Methyl Ethyl Ketone Peroxide	1338-23-4	176											
Methyl Isobutyl Ketone	108-10-1	100											
Methyl Methacrylate	80-62-6	100	2.00E+01	F	3.70E+01	E	2.43E-01	840	&	0.79	I		
Methyl Parathion	298-00-0	263	6.00E+01	L	9.70E-06	E	5.59E-08	460	&	1.91	I	45	F
2-Methyl-4-chlorophenoxyacetic Acid	94-74-6	201											
2(2-Methyl)-4-Chlorophenoxy-propionic Acid	93-65-2	215											

Date Prepared: October 1, 1986

EXHIBIT C-1
(Continued)

PHYSICAL, CHEMICAL, AND FATE DATA

Chemical Name	CAS #	Mole Weight (g/mole)	Water Solubility (mg/l)	S*	Vapor Pressure (mm Hg)	S*	Henry's Law Constant (atm-m3/mol)	Koc (ml/g)	S*	Log Kow	S*	Fish BCF (l/kg)	S*
3-Methylcholanthrene	56-49-3	268					NA						
4,4'-Methylene-bis-2-chloroaniline	101-14-4	267					NA						
Methylnitrosourea	684-93-5	103	6.89E+08	B			NA	0.1	&	-3.81	B		
Methylthiouracil	56-04-2	142					NA						
Methylvinylnitrosamine	4549-40-0	86	7.60E+05	B	1.23E+01	B	1.83E-06	2.5	&	-0.23	B		
N-Methyl-N'-nitro-N-nitrosoguanadin	70-25-7	147					NA						
Mitomycin C	50-07-7	334					NA						
Mustard Gas	505-60-2	159	8.00E+02	B	1.70E-01	B	4.45E-05	110	&	1.37	B		
1-Napthylamine	134-32-7	143	2.35E+03	B	6.50E-05	B	5.21E-09	61	&	2.07	B		
2-Napthylamine	91-59-8	143	5.86E+02	B	2.56E-04	B	8.23E-08	130	&	2.07	B		
Nickel and Compounds	7440-02-0	59			0.00E+00	D	NA					47	H
Nitric Oxide	10102-43-9	30											
Nitrobenzene	98-95-3	123	1.90E+03	C	1.50E-01	B		36	C	1.85	D		
Nitrogen Dioxide	10102-44-0	46											
Nitrosomethylurethane	615-53-2	132					NA						
N-Nitrosopiperidine	100-75-4	114	1.90E+06	B	1.40E-01	B	1.11E-08	1.5	&	-0.49	B		
N-Nitrosopyrrolidine	930-55-2	100	7.00E+06	B	1.10E-01	B	2.07E-09	0.8	&	-1.06	B		
5-Nitro-o-toluidine	99-55-8	152					NA						
Osmium Tetroxide	20816-12-0	254											
Pentachlorobenzene	608-93-5	250	1.35E-01	F			NA	13000	&	5.19	F	2125	H
Pentachloronitrobenzene	82-68-8	295	7.11E-02	B	1.13E-04	B	6.18E-04	19000	&	5.45	B		
Pentachlorophenol	87-86-5	266	1.40E+01	C	1.10E-04	C	2.75E-06	53000	C	5	C	770	G
Phenacetin	62-44-2	179					NA						
Phenanthrene	85-01-8	178	1.00E+00	A	6.80E-04	A	1.59E-04	14000	C	4.46	A	2630	G
Phenobarbital	50-06-6	232	1.00E+03	B			NA	98	&	-0.19	B		
Phenol	108-95-2	94	9.30E+04	A	3.41E-01	A	4.54E-07	14.2	C	1.46	A	1.4	H
Phenylalanine Mustard	148-82-3	305					NA						
m-Phenylenediamine	108-45-2	108											
Phenyl Mercuric Acetate	62-38-4	337	1.67E+03	K									
Phosphine	7803-51-2	34											
Polychlorinated Biphenyls (PCBs)	1336-36-3	328	3.10E-02	C	7.70E-05	C	1.07E-03	530000	C	6.04	C	100000	G
Propane Sultone	1120-71-4	122					NA						
Propylenimine	75-55-8	57	9.44E+05	B	1.41E+02	B	1.12E-05	2.3	&	-0.48	B		
Pyrene	129-00-0	202	1.32E-01	A	2.50E-06	A	5.04E-06	38000	C	4.88	A		
Pyridine	110-86-1	79	1.00E+06	F	2.00E+01	F				0.66	F		
Saccharin	81-07-2	183					NA						
Safrole	94-59-7	162	1.50E+03	B	9.10E-04	B	1.29E-07	78	&	2.53	B		
Selenium and Compounds	7782-49-2	79			0.00E+00	E	NA					16	H
-- Selenious Acid	7783-00-8	129											
-- Selenourea	630-10-4	123											
-- Thallium Selenite	12039-52-0	488											
Silver and Compounds	7440-22-4	108			0.00E+00	D	NA					3080	D
Sodium Diethyldithiocarbamate	148-18-5	171											
Streptozocin	18883-66-4	457					NA						
Strychnine	57-24-9	334	1.56E+02	E									
Styrene	100-42-5	104											
1,2,4,5-Tetrachlorobenzene	95-94-3	216	6.00E+00	F			NA	1600	&	4.67	F	1125	H
2,3,7,8-TCDD (Dioxin)	1746-01-6	322	2.00E-04	A	1.70E-06	A	3.60E-03	3300000	C	6.72	A	5000	H
1,1,1,2-Tetrachloroethane	630-20-6	168	2.90E+03	J	5.00E+00	J	3.81E-04	54	&				
1,1,2,2-Tetrachloroethane	79-34-5	168	2.90E+03	A	5.00E+00	A	3.81E-04	118	C	2.39	A	42	H
Tetrachloroethylene	127-18-4	166	1.50E+02	A	1.78E+01	A	2.59E-02	364	C	2.6	A	31	H
2,3,4,6-Tetrachlorophenol	58-90-2	232	1.00E+03	F			NA	98	&	4.1	F	240	H
2,3,5,6-Tetrachloroterephthalate Acid (DCPA)	1861-32-1	332											

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Date Prepared: October 1, 1986

EXHIBIT C-1
(Continued)

PHYSICAL, CHEMICAL, AND FATE DATA

Chemical Name	CAS #	Mole Weight (g/mole)	Water Solubility (mg/l)	S*	Vapor Pressure (mm Hg)	S*	Henry's Law Constant (atm-m3/mol)	Koc (ml/g)	S*	Log Kow	S*	Fish BCF (l/kg)	S*
Tetraethyl Lead	78-00-2	323	8.00E-01	J	1.50E-01	J	7.97E-02	4900	&				
Thallium and Compounds	7440-28-0	204			0.00E+00	E							
-- Thallium Acetate	563-68-8	263											
-- Thallium Carbonate	6533-73-9	469											
-- Thallium Chloride	7791-12-0	240	2.90E+03	E	0.00E+00	E							
-- Thallium Nitrate	10102-45-1	266											
-- Thallic Oxide	1314-32-5	457											
-- Thallium Sulfate	7446-18-6	505	2.00E+02	E	0.00E+00	E							
Thioacetamide	62-55-5	75					NA			-0.46	J		
Thiourea	62-56-6	76	1.72E+06	B			NA	1.6	&	-2.05	B		
o-Tolidine	119-93-7	212	7.35E+01	B			NA	410	&	2.88	B		
Toluene	108-88-3	92	5.35E+02	A	2.81E+01	A	6.37E-03	300	C	2.73	A	10.7	H
o-Toluidine Hydrochloride	636-21-5	144	1.50E+04	J	1.00E-01	J	9.39E-07	22	&	1.29	J		
Toxaphene	8001-35-2	414	5.00E-01	C	4.00E-01	C	4.36E-01	964	C	3.3	C	13100	H
Tribromomethane (Bromoform)	75-25-2	253	3.01E+03	C	5.00E+00	C	5.52E-04	116	C	2.4	C		
1,2,4-Trichlorobenzene	120-82-1	181	3.00E+01	C	2.90E-01	C	2.31E-03	9200	C	4.3	C	2800	G
1,1,1-Trichloroethane	71-55-6	133	1.50E+03	A	1.23E+02	A	1.44E-02	152	C	2.5	C	5.6	H
1,1,2-Trichloroethane	79-00-5	133	4.50E+03	A	3.00E+01	A	1.17E-03	56	C	2.47	A	5	H
Trichloroethylene	79-01-6	131	1.10E+03	A	5.79E+01	A	9.10E-03	126	C	2.38	A	10.6	H
Trichlorfon	52-68-6	257	1.54E+05	E	7.80E-06	E	1.74E-11	6.1	&	2.29	A		
Trichloromonofluoromethane	75-69-4	137	1.10E+03	C	6.67E+02	C		159	C	2.53	D		
2,4,5-Trichlorophenol	95-95-4	197	1.19E+03	A	1.00E+00	A	2.18E-04	89	&	3.72	A	110	H
2,4,6-Trichlorophenol	88-06-2	197	8.00E+02	A	1.20E-02	A	3.90E-06	2000	C	3.87	A	150	H
2,4,5-Trichlorophenoxyacetic Acid	93-76-5	255											
1,2,3-Trichloropropane	96-18-4	147											
1,1,2-Trichloro-1,2,2,-trifluoroethane	76-13-1	187	1.00E+01	F	2.70E+02	F				2.00	I		
Tris(2,3-dibromopropyl)phosphate	126-72-7	698	1.20E+02	B			NA	310	&	4.12	B	2.7	G
Trinitrotoluene (TNT)	118-96-7	227											
Trypan Blue	72-57-1	961					NA						
Uracil Mustard	66-75-1	252	6.41E+02	B			NA	120	&	-1.09	B		
Uranium and Compounds	7440-61-1	238					NA						
Urethane	51-79-6	89					NA						
Vanadium and Compounds	7440-62-2	51					NA						
Vinyl Chloride	75-01-4	63	2.67E+03	A	2.66E+03	A	8.19E-02	57	&	1.38	A	1.17	H
Warfarin	81-81-2	308											
o-Xylene	95-47-6	106	1.75E+02	F	1.00E+01	E				2.95	I		
m-Xylene	108-38-3	106	1.30E+02	F	1.00E+01	F				3.26	I		
p-Xylene	106-42-3	106	1.98E+02	F	1.00E+01	F				3.15	I		
Xylene (mixed)	1330-20-7	106	1.98E+02	F	1.00E+01	F	7.04E-03	240	&	3.26	I		
Zinc and Compounds	7440-66-6	65			0.00E+00	D	NA					47	H
-- Zinc Phosphide	1314-84-7	258											
Zineb	12122-67-7	276											

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* Letters denote the source of the data, as listed in Section 3.1.
# Solubility of 1,000,000 mg/l assigned because of reported "infinite solubility" in the literature.
& Koc estimated by the following equation: log Koc = (-0.55*logS) + 3.64 (Note: S in mg/l).

Date Prepared: October 1, 1986

EXHIBIT C-2

HALF-LIVES IN VARIOUS MEDIA

Chemical Name	CAS #	Half-Life Range (Days)											
		Soil			Air			Surface Water			Ground Water		
		Low	High	S*	Low	High	S*	Low	High	S*	Low	High	S*
Acenaphthene	83-32-9												
Acenaphthylene	208-96-8				5.50	-	M	0.125	-	M			
Acetone	67-64-1												
Acetonitrile	75-05-8				390.00	-	M	7.00	-	M			
2-Acetylaminofluorene	53-96-3												
Acrylic Acid	79-10-7												
Acrylonitrile	107-13-1				3.90	-	M	2.10	7.00	M			
Aflatoxin B1	1162-65-8												
Aldicarb	116-06-3												
Aldrin	309-00-2												
Allyl Alcohol	107-18-6							5.00	-	M			
Aluminum Phosphide	20859-73-8												
4-Aminobiphenyl	92-67-1												
Amitrole	61-82-5												
Ammonia	7664-41-7												
Anthracene	120-12-7												
Antimony and Compounds	7440-36-0				4.80	-	M	PERS**	-	M			
Arsenic and Compounds	7440-38-2				5.00	-	M	PERS	-	M			
Asbestos	1332-21-4				4.80	-	M	PERS	-	M			
Auramine	2465-27-2												
Azaserine	115-02-6												
Aziridine	151-56-4												
Barium and Compounds	7440-39-3				4.80	-	M	PERS	-	M			
Benefin	1861-40-1												
Benzene	71-43-2				6.00	-	A	1.00	6.00	A			
Benzidine	92-87-5												
Benz(a)anthracene	56-55-3				5.50	-	M	0.10	5.00	M			
Benz(c)acridine	225-51-4												
Benzo(a)pyrene	50-32-8	420.00	480.00	A	1.00	6.00	A	0.40	-	A			
Benzo(b)fluoranthene	205-99-2				5.50	-	M	1.00	2.00	M			
Benzo(ghi)perylene	191-24-2												
Benzo(k)fluoranthene	207-08-9												
Benzotrichloride	98-07-7												
Benzyl Chloride	100-44-7							1.50	-	M			
Beryllium and Compounds	7440-41-7												
1,1-Biphenyl	92-52-4												
Bis(2-chloroethyl)ether	111-44-4												
Bis(2-chloroisopropyl)ether	108-60-1												
Bis(chloromethyl)ether	542-88-1				0.14	2.00	M	0.0007	-	M			
Bis(2-ethylhexyl)phthalate (DEHP)	117-81-7												
Bromomethane	74-83-9												
Bromoxynil Octanoate	1689-99-2												
1,3-Butadiene	106-99-0												
n-Butanol	71-36-3												
Butylphthalyl Butylglycolate	85-70-1												
Cacodylic Acid	75-60-5												
Cadmium and Compounds	7740-43-9				4.80	-	M	PERS	-	M			
Captan	133-06-2												
Carbaryl	63-25-2												
Carbon Disulfide	75-15-0												
Carbon Tetrachloride	56-23-5				8030.00	-	A	0.30	300.00	A			
Chlordane	57-74-9				40.00	-	M	420.00	500.00	A			
Chlorobenzene	108-90-7				3.50	-	A	0.30	-	A			
Chlorobenzilate	510-15-6												

Date Prepared: October 1, 1986

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EXHIBIT C-2
(Continued)

HALF-LIVES IN VARIOUS MEDIA

Chemical Name	CAS #	Half-Life Range (Days) Soil Low	Soil High	S*	Air Low	Air High	S*	Surface Water Low	Surface Water High	S*	Ground Water Low	Ground Water High	S*
Chlorodibromomethane	124-48-1												
Chloroform	67-66-3				80.00	-	A	0.30	30.00	A			
Chloromethyl Methyl Ether	107-30-2												
4-Chloro-o-toluidine Hydrochloride	3165-93-3												
Chromium III and Compounds	7440-47-3												
Chromium VI and Compounds	7440-47-3				4.80	-	M	3.00	-	M			
Chrysene	218-01-9				5.50	-	M	0.20	-	M			
Copper and Compounds	7440-50-8												
Creosote	8001-58-9												
Cresol	1319-77-3												
Crotonaldehyde	123-73-9												
Cyanides	57-12-5				73000.00	-	M	0.33	0.80	M			
-- Barium Cyanide	542-62-1												
-- Calcium Cyanide	592-01-8												
-- Copper Cyanide	544-92-3												
-- Cyanogen	460-19-5												
-- Cyanogen Chloride	506-77-4												
-- Hydrogen Cyanide	74-90-8												
-- Nickel Cyanide	557-19-7												
-- Potassium Cyanide	151-50-8												
-- Potassium Silver Cyanide	506-61-6												
-- Silver Cyanide	506-64-9												
-- Sodium Cyanide	143-33-9												
-- Zinc Cyanide	557-21-1												
Cyclophosphamide	50-18-0												
Dalapon	75-99-0												
DDD	72-54-8												
DDE	72-55-9												
DDT	50-29-3	1000.00	5500.00	A				56.00	110.00	A			
Decabromodiphenyl Ether	1163-19-5												
Diallate	2303-16-4												
2,4-Diaminotoluene	95-80-7												
1,2,7,8-Dibenzopyrene	189-55-9												
Dibenz(a,h)anthracene	53-70-3				5.50	-	M	0.0208	2.08	M			
1,2-Dibromo-3-chloropropane	96-12-8												
Dibutylnitrosamine	924-16-3												
Dibutyl Phthalate	84-74-2												
1,2-Dichlorobenzene	95-50-1				26.00	-	M	1.50	8.50	M			
1,3-Dichlorobenzene	541-73-1												
1,4-Dichlorobenzene	106-46-7				23.00	-	M	1.50	8.50	M			
3,3'-Dichlorobenzidine	91-94-1												
Dichlorodifluoromethane	75-71-8												
1,1-Dichloroethane	75-34-3				45.00	-	A	1.00	5.00	A			
1,2-Dichloroethane (EDC)	107-06-2				36.00	127.00	A	0.17	-	A			
1,1-Dichloroethylene	75-35-4				2.00	-	A	1.00	6.00	A			
1,2-Dichloroethylene (trans)	540-59-0				2.10	-	A	1.00	6.00	A			
1,2-Dichloroethylene (cis)	540-59-0				1.30	-	A	1.00	6.00	A			
Dichloromethane	75-09-2				53.20	-	M	1.20	5.80	M			
2,4-Dichlorophenol	120-83-2				2.30	-	M	6.00	-	M			
2,4-Dichlorophenoxyacetic Acid (2,4-D)	94-75-7												
4-(2,4-Dichlorophenoxy)butyric Acid (2,4-DB)	94-82-6												

Date Prepared: October 1, 1986

EXHIBIT C-2
(Continued)

HALF-LIVES IN VARIOUS MEDIA

Chemical Name	CAS #	Half-Life Range (Days)											
		Soil			Air			Surface Water			Ground Water		
		Low	High	S*	Low	High	S*	Low	High	S*	Low	High	S*
Dichlorophenylarsine	696-28-6												
1,2-Dichloropropane	78-87-5				80.00	-	M	1.40	7.70	M			
1,3-Dichloropropene	542-75-6							1.00	-	M			
Dieldrin	60-57-1												
Diepoxybutane	1464-53-5												
Diethanolnitrosamine	1116-54-7												
Diethyl Arsine	692-42-2												
1,2-Diethylhydrazine	1615-80-1												
Diethylnitrosamine	55-18-5												
Diethyl Phthalate	84-66-2												
Diethylstilbestrol (DES)	56-53-1												
Dihydrosafrole	94-58-6												
Dimethoate	60-51-5												
3,3'-Dimethoxybenzidine	119-90-4												
Dimethylamine	124-40-3												
Dimethyl Sulfate	77-78-1												
Dimethyl Terephthalate	120-61-6												
Dimethylaminoazobenzene	60-11-7												
7,12-Dimethylbenz(a)anthracene	57-97-6												
3,3'-Dimethylbenzidine	119-93-7												
Dimethylcarbamoyl Chloride	79-44-7												
1,1-Dimethylhydrazine	57-14-4												
1,2-Dimethylhydrazine	540-73-8												
Dimethylnitrosamine	62-75-9												
1,3-Dinitrobenzene	99-65-0							96.00	-	M			
4,6-Dinitro-o-cresol	534-52-1												
2,4-Dinitrophenol	51-28-5												
2,3-Dinitrotoluene	602-01-7												
2,4-Dinitrotoluene	121-14-2				133.00	-	M	0.40	10.00	M			
2,5-Dinitrotoluene	619-15-8												
2,6-Dinitrotoluene	606-20-2												
3,4-Dinitrotoluene	610-39-9												
Dinoseb	88-85-7												
1,4-Dioxane	123-91-1												
N,N-Diphenylamine	122-39-4												
1,2-Diphenylhydrazine	122-66-7												
Dipropylnitrosamine	621-64-7												
Disulfoton	298-04-4												
Endosulfan	115-29-7												
Epichlorohydrin	106-89-8				2.70	-	M	3.50	10.80	M			
Ethanol	64-17-5												
Ethyl Acetate	141-78-6												
Ethyl Methanesulfonate	62-50-0												
Ethylbenzene	100-41-4				1.46	-	A	1.50	7.50	A			
Ethyl-4,4'-dichlorobenzilate	510-15-6												
Ethylene Dibromide (EDB)	106-93-4												
Ethylene Oxide	75-21-8												
Ethylenethiourea	96-45-7												
1-Ethyl-nitrosourea	759-73-9												
Ethylphthalyl Ethyl Glycolate	84-72-0												
Ferric Dextran	9004-66-4												
Fluoranthene	206-44-0				5.50	-	M	1.00	2.00	M			
Fluorene	86-73-7												

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Date Prepared: October 1, 1986

EXHIBIT C-2
(Continued)

HALF-LIVES IN VARIOUS MEDIA

Chemical Name	CAS #	Half-Life Range (Days)											
		Soil			Air			Surface Water			Ground Water		
		Low	High	S*	Low	High	S*	Low	High	S*	Low	High	S*
Fluorides	7782-41-4												
Fluridone	59756-60-4												
Formaldehyde	50-00-0				0.80	-	M	0.90	3.50	M			
Formic Acid	64-18-6												
Furan	110-00-9												
Glycidaldehyde	765-34-4												
Glycol Ethers	NA												
-- Diethylene Glycol, Monoethyl Ether	111-90-0												
-- 2-Ethoxyethanol	110-80-5												
-- Ethylene Glycol, Monobutyl Ether	111-76-2												
-- 2-Methoxyethanol	109-86-4												
-- Propylene Glycol, Monoethyl Ether	52125-53-8												
-- Propylene Glycol, Monomethyl Ether	107-98-2												
Heptachlor	76-44-8				40.00	-	M	0.96	-	M			
Heptachlor Epoxide	1024-57-3												
Hexachlorobenzene	118-74-1	1100.00	2200.00	A	80.00	-	M	0.30	300.00	A			
Hexachlorobutadiene	87-68-3				0.20	-	M	29.00	2300.00	A			
Hexachlorocyclopentadiene	77-47-4				0.14	-	M	0.007	-	M			
alpha-Hexachlorocyclohexane (HCCH)	319-84-6												
beta-HCCH	319-85-7												
gamma-HCCH (Lindane)	58-89-9												
delta-HCCH	319-86-8												
Hexachloroethane	67-72-1				7900	-	M	1.10	9.50	M			
Hexachlorophene	70-30-4												
Hydrazine	302-01-1												
Hydrogen Sulfide	7783-06-4												
Indeno(1,2,3-cd)pyrene	193-39-5				5.50	-	M	0.0208	2.08	M			
Iodomethane	77-88-4												
Iron and Compounds	15438-31-0												
Isobutanol	78-83-1												
Isoprene	78-79-5												
Isosafrole	120-58-1												
Isophorone	78-59-1												
Isopropalin	33820-53-0												
Kepone	143-50-0												
Lasiocarpine	303-34-4												
Lead and Compounds (Inorganic)	7439-92-1				4.80	-	M	PERS	-	M			
Linuron	330-55-2												
Malathion	121-75-7												
Manganese and Compounds	7439-96-5												
Melphalan	148-82-3												
Mercury and Compounds (Alkyl)	7439-97-6												
Mercury and Compounds (Inorganic)	7439-97-6				4.80	-	M	PERS	-	M			
Mercury Fulminate	628-86-4												
Methanol	67-56-1												
Methyl Chloride	74-87-3							1.00	-	M			
Methyl Ethyl Ketone	78-93-3				0.58	-	A	10.00	-	A			
Methyl Ethyl Ketone Peroxide	1338-23-4												
Methyl Isobutyl Ketone	108-10-1												

EXHIBIT C-2
(Continued)

HALF-LIVES IN VARIOUS MEDIA

Chemical Name	CAS #	Half-Life Range (Days)											
		Soil			Air			Surface Water			Ground Water		
		Low	High	S*	Low	High	S*	Low	High	S*	Low	High	S*
Methyl Methacrylate	80-62-6							15.00	-	M			
Methyl Parathion	298-00-0												
2-Methyl-4-chlorophenoxyacetic Acid	94-74-6												
2(2-Methyl)-4-Chlorophenoxy-propionic Acid	93-65-2												
3-Methylcholanthrene	56-49-5												
4,4'-Methylene-bis-2-chloroaniline	101-14-4												
Methylnitrosourea	684-93-5												
Methylthiouracil	56-04-2												
Methylvinylnitrosamine	4549-40-0												
N-Methyl-N'-nitro-N-nitrosoguanadine	70-25-7												
Mitomycin C	50-07-7												
Mustard Gas	505-60-2												
1-Napthylamine	134-32-7												
2-Napthylamine	91-59-8												
Nickel and Compounds	7440-02-0												
Nitric Oxide	10102-43-9												
Nitrobenzene	98-95-3							12.50	-	M			
Nitrogen Dioxide	10102-44-0												
Nitrosomethylurethane	615-53-2												
N-Nitrosopiperidine	100-75-4												
N-Nitrosopyrrolidine	930-55-2												
5-Nitro-o-toluidine	99-55-8												
Osmium Tetroxide	20816-12-0												
Pentachlorobenzene	608-93-5												
Pentachloronitrobenzene	82-68-8												
Pentachlorophenol	87-86-5				21.00	-	M	5.00	-	M			
Phenacetin	62-44-2												
Phenanthrene	85-01-8							0.38	2.00	A			
Phenobarbital	50-06-6												
Phenol	108-95-2				0.62	9.00	A	0.62	9.00	A			
Phenylalanine Mustard	148-82-3												
m-Phenylenediamine	108-45-2												
Phenyl Mercuric Acetate	62-38-4												
Phosphine	7803-51-2												
Polychlorinated Biphenyls (PCBs)	1336-36-3				58.00	-	M	2.00	12.90	M			
Propane Sultone	1120-71-4												
Propylenimine	75-55-8												
Pyrene	129-00-0				0.08	2.00	A						
Pyridine	110-86-1							2.00	-	M			
Saccharin	81-07-2												
Safrole	94-59-7												
Selenium and Compounds	7782-49-2												
-- Selenious Acid	7783-00-8												
-- Selenourea	630-10-4												
-- Thallium Selenite	12039-52-0												
Silver and Compounds	7440-22-4												
Sodium Diethyldithiocarbamate	148-18-5												
Streptozocin	18883-66-4												
Strychnine	57-24-9												
Styrene	100-42-5												
1,2,4,5-Tetrachlorobenzene	95-94-3												
2,3,7,8-TCDD (Dioxin)	1746-01-6	3650.00	4380.00	A				365.00	730.00	A			

Date Prepared: October 1, 1986

EXHIBIT C-2
(Continued)

HALF-LIVES IN VARIOUS MEDIA

		Half-Life Range (Days)											
		Soil			Air			Surface Water			Ground Water		
Chemical Name	CAS #	Low	High	S*	Low	High	S*	Low	High	S*	Low	High	S*
1,1,1,2-Tetrachloroethane	630-20-6							1.40	-	M			
1,1,2,2-Tetrachloroethane	79-34-5				584.00	-	A	0.04	-	A			
Tetrachloroethylene	127-18-4				47.00	-	A	1.00	30.00	A			
2,3,4,6-Tetrachlorophenol	58-90-2												
2,3,5,6-Tetrachloroterephthalate Acid (DCPA)	1861-32-1												
Tetraethyl Lead	78-00-2												
Thallium and Compounds	7440-28-0												
-- Thallium Acetate	563-68-8												
-- Thallium Carbonate	6533-73-9												
-- Thallium Chloride	7791-12-0												
-- Thallium Nitrate	10102-45-1												
-- Thallic Oxide	1314-32-5												
-- Thallium Sulfate	7446-18-6												
Thioacetamide	62-55-5												
Thiourea	62-56-6												
o-Tolidine	119-93-7												
Toluene	108-88-3				1.30	-	A	0.17	-	A			
o-Toluidine Hydrochloride	636-21-5												
Toxaphene	8001-35-2				40.00	-	M	2.00	14.20	M			
Tribromomethane (Bromoform)	75-25-2												
1,2,4-Trichlorobenzene	120-82-1							1.20	-	M			
1,1,1-Trichloroethane	71-55-6				803.00	1752.00	A	0.14	7.00	A			
1,1,2-Trichloroethane	79-00-5				24.00	-	A	1.90	-	A			
Trichloroethylene	79-01-6				3.70	-	A	1.00	90.00	A			
Trichlorfon	52-68-6												
Trichloromonofluoromethane	75-69-4												
2,4,5-Trichlorophenol	95-95-4	72.00	-	A									
2,4,6-Trichlorophenol	88-06-2	5.00	-	A	1.00	-	A	1.00	19.00	A			
2,4,5-Trichlorophenoxyacetic Acid	93-76-5												
1,2,3-Trichloropropane	96-18-4												
1,1,2-Trichloro-1,2,2,-trifluoroethane	76-13-1												
Tris(2,3-dibromopropyl)phosphate	126-72-7												
Trinitrotoluene (TNT)	118-96-7												
Trypan Blue	72-57-1												
Uracil Mustard	66-75-1												
Uranium and Compounds	7440-61-1												
Urethane	51-79-6												
Vanadium and Compounds	7440-62-2												
Vinyl Chloride	75-01-4				1.20	-	A	1.00	5.00	A			
Warfarin	81-81-2												
o-Xylene	95-47-6												
m-Xylene	108-38-3												
p-Xylene	106-42-3												
Xylene (mixed)	1330-20-7				0.50	-	M	1.50	9.00	M			
Zinc and Compounds	7440-66-6				4.80	20.00	M	PERS	-	M			
-- Zinc Phosphide	1314-84-7												
Zineb	12122-67-7												

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* Letters denote the source of the data, as listed in Section C.1.
** PERS indicates the chemical is persistent for that medium.

EXHIBIT C-3

TOXICITY DATA FOR POTENTIAL CARCINOGENIC EFFECTS -- SELECTION OF INDICATOR CHEMICALS ONLY [1]--

	Oral Route			Inhalation Route	
Chemical Name	10% Effective Dose (ED10) mg/kg/day	Toxicity Constant Water (wTc) l/mg	Toxicity Constant Soil (sTc) kg/mg	10% Effective Dose (ED10) mg/kg/day	Air Toxicity Constant (aTc) (m3/mg)
2-Acetylaminofluorene	2.60E-02	1.10E+00	5.50E-05	2.60E-02	1.10E+01
Acrylonitrile	4.39E-01	6.51E-02	3.26E-06	4.39E-01	6.51E-01
Aflatoxin B1	NA	NA	NA	NA	NA
Aldrin	1.52E-02	1.88E+00	9.40E-05	1.52E-02	1.88E+01
Amitrole	1.89E-01	1.51E-01	7.56E-06	1.89E-01	1.51E+00
Arsenic and Compounds	7.03E-03	4.07E+00	2.03E-04	7.03E-03	4.07E+01
Asbestos	NA	NA	NA	NA	NA
Auramine	1.08E+00	2.66E-02	1.33E-06	1.08E+00	2.66E-01
Azaserine	NA	NA	NA	NA	NA
Aziridine	3.60E-03	7.93E+00	3.97E-04	3.60E-03	7.93E+01
Benzene	3.70E+00	7.71E-03	3.86E-07	3.70E+00	7.71E-02
Benzidine	4.50E-04	6.34E+01	3.17E-03	4.50E-04	6.34E+02
Benz(a)anthracene	4.92E-02	5.81E-01	2.91E-05	4.92E-02	5.81E+00
Benz(c)acridine	6.67E-05	4.29E+02	2.14E-02	6.67E-05	4.29E+03
Benzo(a)pyrene	6.28E-03	4.55E+00	2.28E-04	6.28E-03	4.55E+01
Benzo(b)fluoranthene	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	NA	NA	NA	NA	NA
Benzotrichloride	8.91E-03	3.21E+00	1.60E-04	8.91E-03	3.21E+01
Benzyl Chloride	NA	NA	NA	NA	NA
Beryllium and Compounds	NA	NA	NA	1.25E-02	2.28E+01
Bis(2-chloroethyl)ether	8.23E-02	3.47E-01	1.74E-05	8.23E-02	3.47E+00
Bis(chloromethyl)ether	7.22E-04	3.96E+01	1.98E-03	7.22E-04	3.96E+02
Bis(2-ethylhexyl)phthalate (DEHP)	5.00E+01	5.71E-04	2.86E-08	5.00E+01	5.71E-03
Cacodylic Acid	NA	NA	NA	NA	NA
Cadmium and Compounds	NA	NA	NA	1.73E-02	1.65E+01
Carbon Tetrachloride	1.52E-02	1.88E+00	9.41E-05	1.52E-02	1.88E+01
Chlordane	6.61E-02	4.32E-01	2.16E-05	6.61E-02	4.32E+00
Chloroform	5.08E-01	5.63E-02	2.81E-06	5.08E-01	5.63E-01
4-Chloro-o-toluidine Hydrochloride	8.13E-01	3.51E-02	1.76E-06	8.13E-01	3.51E-01
Chromium VI and Compounds	NA	NA	NA	2.57E-03	1.11E+02
Chrysene	NA	NA	NA	NA	NA
Cyclophosphamide	5.70E-02	5.01E-01	2.50E-05	5.70E-02	5.01E+00
DDD	7.69E-01	3.71E-02	1.86E-06	7.69E-01	3.71E-01
DDE	2.53E-01	1.13E-01	5.64E-06	2.53E-01	1.13E+00
DDT	1.79E-01	1.59E-01	7.97E-06	1.79E-01	1.59E+00
Diallate	4.24E-01	6.74E-02	3.37E-06	4.24E-01	6.74E-01

Date Prepared: October 1, 1986

EXHIBIT C-3
(Continued)

TOXICITY DATA FOR POTENTIAL CARCINOGENIC EFFECTS -- SELECTION OF INDICATOR CHEMICALS ONLY

	Oral Route			Inhalation Route	
	10% Effective Dose (ED10)	Toxicity Constant		10% Effective Dose (ED10)	Air Toxicity Constant (aTc)
Chemical Name	mg/kg/day	Water (wTc) 1/mg	Soil (sTc) kg/mg	mg/kg/day	m3/mg
Diaminotoluene (mixed)	3.40E-01	8.40E-02	4.20E-06	3.40E-01	8.40E-01
1,2,7,8-Dibenzopyrene	NA	NA	NA	NA	NA
Dibenz(a,h)anthracene	2.83E-03	1.01E+01	5.04E-04	2.83E-03	1.01E+02
1,2-Dibromo-3-chloropropane	6.00E-03	4.76E+00	2.38E-04	6.00E-03	4.76E+01
Dibutylnitrosamine	2.29E-02	1.25E+00	6.24E-05	2.29E-02	1.25E+01
3,3'-Dichlorobenzidine	1.20E-01	2.39E-01	1.19E-05	1.20E-01	2.39E+00
1,2-Dichloroethane (EDC)	4.88E-01	5.86E-02	2.93E-06	4.88E-01	5.86E-01
1,1-Dichloroethylene	2.33E-01	1.23E-01	6.14E-06	2.33E-01	1.23E+00
Dichloromethane	NA	NA	NA	NA	NA
Dieldrin	7.81E-03	3.66E+00	1.83E-04	7.81E-03	3.66E+01
Diepoxybutane	3.58E-02	7.98E-01	3.99E-05	3.58E-02	7.98E+00
Diethanolnitrosamine	NA	NA	NA	NA	NA
Diethyl Arsine	NA	NA	NA	NA	NA
1,2-Diethylhydrazine	NA	NA	NA	NA	NA
Diethylnitrosamine	1.03E-03	2.77E+01	1.38E-03	1.03E-03	2.77E+02
Diethylstilbestrol (DES)	2.11E-04	1.35E+02	6.77E-03	2.11E-04	1.35E+03
Dihydrosafrole	9.26E-01	3.09E-02	1.54E-06	9.26E-01	3.09E-01
3,3'-Dimethoxybenzidine	2.00E+01	1.43E-03	7.14E-08	2.00E+01	1.43E-02
Dimethyl Sulfate	NA	NA	NA	NA	NA
Dimethylaminoazobenzene	9.52E-03	3.00E+00	1.50E-04	9.52E-03	3.00E+01
7,12-Dimethylbenz(a)anthracene	5.23E-06	5.46E+03	2.73E-01	5.23E-06	5.46E+04
3,3'-Dimethylbenzidene	3.70E-02	7.71E-01	3.86E-05	3.70E-02	7.72E+00
Dimethylcarbamoyl Chloride	1.98E-03	1.44E+01	7.22E-04	1.98E-03	1.44E+02
1,1-Dimethylhydrazine	7.44E-02	3.84E-01	1.92E-05	7.44E-02	3.84E+00
1,2-Dimethylhydrazine	1.87E-04	1.53E+02	7.65E-03	1.87E-04	1.53E+03
Dimethylnitrosamine	3.91E-02	7.30E-01	3.65E-05	3.91E-02	7.30E+00
Dinitrotoluene (mixed)	2.62E-01	1.09E-01	5.46E-06	2.62E-01	1.09E+00
2,4-Dinitrotoluene	2.62E-01	1.09E-01	5.46E-06	2.62E-01	1.09E+00
2,6-Dinitrotoluene	NA	NA	NA	NA	NA
1,4-Dioxane	2.94E+01	9.71E-04	4.86E-08	2.94E+01	9.71E-03
1,2-Diphenylhydrazine	2.19E-01	1.31E-01	6.53E-06	2.19E-01	1.31E+00
Dipropylnitrosamine	NA	NA	NA	NA	NA
Epichlorohydrin	2.70E+00	1.06E-02	5.29E-07	2.70E+00	1.06E-01
Ethyl-4,4'-dichlorobenzilate	5.59E-01	5.11E-02	2.56E-06	5.59E-01	5.11E-01
Ethylene Dibromide (EDB)	2.56E-03	1.11E+01	5.57E-04	2.56E-03	1.11E+02
Ethylene Oxide	4.13E-01	6.91E-02	3.46E-06	4.13E-01	6.91E-01

Date Prepared: October 1, 1986

EXHIBIT C-3
(Continued)

TOXICITY DATA FOR POTENTIAL CARCINOGENIC EFFECTS -- SELECTION OF INDICATOR CHEMICALS ONLY

	Oral Route			Inhalation Route	
	10% Effective Dose (ED10)	Toxicity Constant		10% Effective Dose (ED10)	Air Toxicity Constant (aTc)
Chemical Name	mg/kg/day	Water (wTc) 1/mg	Soil (sTc) kg/mg	mg/kg/day	m3/mg
Ethylenethiourea	7.69E-01	3.71E-02	1.86E-06	7.69E-01	3.71E-01
Ethyl Methanesulfonate	5.58E-03	5.12E+00	2.56E-04	5.58E-03	5.12E+01
1-Ethyl-nitrosourea	1.14E-01	2.50E-01	1.25E-05	1.14E-01	2.50E+00
Formaldehyde	4.90E-02	5.83E-01	2.92E-05	4.90E-02	5.83E+00
Glycidaldehyde	3.45E-01	8.29E-02	4.14E-06	3.45E-01	8.29E-01
Heptachlor	8.93E-03	3.20E+00	1.60E-04	8.93E-03	3.20E+01
Heptachlor Epoxide	3.45E-03	8.28E+00	4.14E-04	3.45E-03	8.28E+01
Hexachlorobenzene	8.51E-02	3.36E-01	1.68E-05	8.51E-02	3.36E+00
Hexachlorobutadiene	1.69E+00	1.69E-02	8.43E-07	1.69E+00	1.69E-01
alpha-Hexachlorocyclohexane (HCCH)	1.83E-02	1.56E+00	7.79E-05	1.83E-02	1.56E+01
beta-HCCH	5.75E-01	4.97E-02	2.49E-06	5.75E-01	4.97E-01
gamma-HCCH (Lindane)	5.46E-01	5.23E-02	2.61E-06	5.46E-01	5.23E-01
Hexachloroethane	1.25E+01	2.29E-03	1.14E-07	1.25E+01	2.29E-02
Hydrazine	1.27E-02	2.25E+00	1.13E-04	1.27E-02	2.25E+01
Indeno(1,2,3-cd)pyrene	NA	NA	NA	NA	NA
Iodomethane	NA	NA	NA	NA	NA
Isosafrole	1.67E+00	1.71E-02	8.57E-07	1.67E+00	1.71E-01
Kepone	2.09E-02	1.37E+00	6.85E-05	2.09E-02	1.37E+01
Lasiocarpine	2.66E-02	1.08E+00	5.38E-05	2.66E-02	1.08E+01
Melphalan	9.09E-04	3.14E+01	1.57E-03	9.09E-04	3.14E+02
Methyl Chloride	1.05E+01	2.71E-03	1.36E-07	1.05E+01	2.71E-02
3-Methylcholanthrene	4.64E-02	6.16E-01	3.08E-05	4.64E-02	6.16E+00
4,4'-Methylene-bis-2-chloroaniline	8.20E-01	3.49E-02	1.74E-06	8.20E-01	3.49E-01
Methylnitrosourea	9.48E-05	3.01E+02	1.51E-02	9.48E-05	3.01E+03
Methylnitrosourethane	NA	NA	NA	NA	NA
Methylthiouracil	3.50E-02	8.16E-01	4.08E-05	3.50E-02	8.16E+00
Methylvinylnitrosamine	NA	NA	NA	NA	NA
N-Methyl-N'-nitro-N-nitrosoguanadine	1.79E-02	1.59E+00	7.97E-05	1.79E-02	1.59E+01
Mitomycin C	NA	NA	NA	NA	NA
1-Napthylamine	NA	NA	NA	NA	NA
2-Napthylamine	1.98E-01	1.44E-01	7.21E-06	1.98E-01	1.44E+00
Nickel and Compounds	NA	NA	NA	1.00E-01	2.85E+00
N-Nitrosopiperidine	3.88E-02	7.37E-01	3.68E-05	3.88E-02	7.37E+00
N-Nitrosopyrrolidine	5.36E-03	5.33E+00	2.66E-04	5.36E-03	5.33E+01
5-Nitro-o-toluidine	7.14E+00	4.00E-03	2.00E-07	7.14E+00	4.00E-02
Pentachloronitrobenzene	7.04E-01	4.06E-02	2.03E-06	7.04E-01	4.06E-01

EXHIBIT C-3
(Continued)

TOXICITY DATA FOR POTENTIAL CARCINOGENIC EFFECTS -- SELECTION OF INDICATOR CHEMICALS ONLY

	Oral Route			Inhalation Route	
	10% Effective Dose (ED10) mg/kg/day	Toxicity Constant		10% Effective Dose (ED10) mg/kg/day	Air Toxicity Constant (aTc) m3/mg
Chemical Name		Water (wTc) l/mg	Soil (sTc) kg/mg		
Pentachlorophenol	NA	NA	NA	NA	NA
Phenacetin	1.25E+01	2.29E-03	1.14E-07	1.25E+01	2.29E-02
Polychlorinated Biphenyls (PCBs)	5.00E-02	5.71E-01	2.86E-05	5.00E-02	5.71E+00
Polynuclear Aromatic Hydrocarbons	NA	NA	NA	NA	NA
Propane Sultone	2.85E-02	1.00E+00	5.01E-05	2.85E-02	1.00E+01
1,2-Propylenimine	3.35E-02	8.53E-01	4.27E-05	3.35E-02	8.53E+00
Saccharin	2.44E+02	1.17E-04	5.86E-09	2.44E+02	1.17E-03
Safrole	5.00E+00	5.71E-03	2.86E-07	5.00E+00	5.71E-02
Streptozocin	9.17E-03	3.12E+00	1.56E-04	9.17E-03	3.12E+01
2,3,7,8-TCDD (Dioxin)	8.33E-06	3.43E+03	1.71E-01	8.33E-06	3.43E+04
1,1,1,2-Tetrachloroethane	1.20E+00	2.37E-02	1.19E-06	1.20E+00	2.37E-01
1,1,2,2-Tetrachloroethane	6.02E-01	4.74E-02	2.37E-06	6.02E-01	4.74E-01
Tetrachloroethylene	3.23E+00	8.86E-03	4.43E-07	3.23E+00	8.86E-02
Thioacetamide	4.04E-02	7.07E-01	3.54E-05	4.04E-02	7.07E+00
Thiourea	9.52E-01	3.00E-02	1.50E-06	9.52E-01	3.00E-01
o-Toluidine hydrochloride	6.37E-01	4.49E-02	2.24E-06	6.37E-01	4.49E-01
Toxaphene	1.02E-01	2.80E-01	1.40E-05	1.02E-01	2.80E+00
1,1,2-Trichloroethane	2.78E+00	1.03E-02	5.14E-07	2.78E+00	1.03E-01
Trichloroethylene	6.67E+00	4.29E-03	2.14E-07	6.67E+00	4.29E-02
2,4,6-Trichlorophenol	1.25E+01	2.29E-03	1.14E-07	1.25E+01	2.29E-02
Tris(2,3-dibromopropyl)phosphate	1.02E-01	2.79E-01	1.39E-05	1.02E-01	2.79E+00
Trypan Blue	2.78E+00	1.03E-02	5.14E-07	2.78E+00	1.03E-01
Uracil Mustard	NA	NA	NA	NA	NA
Urethane	1.56E+00	1.83E-02	9.14E-07	1.56E+00	1.83E-01
Vinyl Chloride	6.67E+00	4.29E-03	2.14E-07	6.67E+00	4.29E-02

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[1] The list of chemicals presented in this exhibit is based on EPA's Reportable Quantities Analysis and should not be considered an all-inclusive list of suspected carcinogens. Refer to Exhibit C-4 for toxicity data for risk characterization for the chemicals listed here.

Date Prepared: October 1, 1986

EXHIBIT C-4

TOXICITY DATA FOR POTENTIAL CARCINOGENIC EFFECTS -- RISK CHARACTERIZATION [1]

	Oral Route			Inhalation Route		
Chemical Name	Potency Factor (PF) (mg/kg/d)-1	Source[2]	EPA Weight of Evidence	Potency Factor (PF) (mg/kg/d)-1	Source[2]	EPA Weight of Evidence
2-Acetylaminofluorene			B2			B2
Acrylonitrile			B1	2.40E-01	CAG	B1
Aflatoxin B1	2.90E+03	CAG	B2			B2
Aldrin	1.14E+01	CAG	B2			B2
Amitrole			B2			B2
Arsenic and Compounds	1.50E+01	HEA	A	5.00E+01	HEA	A
Asbestos			A			A
Auramine			B2			B2
Azaserine			B2			B2
Aziridine			B2			B2
Benzene	5.20E-02	HEA	A	2.60E-02	HEA	A
Benzidine			A	2.30E+02	CAG	A
Benz(a)anthracene			B2			B2
Benz(c)acridine			C			C
Benzo(a)pyrene	1.15E+01	HEA	B2	6.10E+00	HEA	B2
Benzo(b)fluoranthene			B2			B2
Benzo(k)fluoranthene			D			D
Benzotrichloride			B2			B2
Benzyl Chloride			C			C
Beryllium and Compounds	NA		B1	4.86E+00	CAG	B1
Bis(2-chloroethyl)ether	1.10E+00	CAG	B2			B2
Bis(chloromethyl)ether			A	9.30E+03	CAG	A
Bis(2-ethylhexyl)phthalate (DEHP)	6.84E-04	CAG	B2			B2
Cacodylic Acid			D			D
Cadmium and Compounds	NA			6.10E+00	HEA	B1
Carbon Tetrachloride	1.30E-01	HEA	B2			B2
Chlordane	1.61E+00	HEA	B2			B2
Chloroform	8.10E-02	HEA	B2			B2
4-Chloro-o-toluidine Hydrochloride			B2			B2
Chromium VI and Compounds	NA			4.10E+01	HEA	A
Chrysene			B2			B2
Cyclophosphamide			B1			B1
DDD			B2			B2
DDE			B2			B2
DDT	3.40E-01	HEA	B2			B2

EXHIBIT C-4
(Continued)

TOXICITY DATA FOR POTENTIAL CARCINOGENIC EFFECTS -- RISK CHARACTERIZATION

	Oral Route			Inhalation Route		
Chemical Name	Potency Factor (PF) (mg/kg/d)-1	Source[2]	EPA Weight of Evidence	Potency Factor (PF) (mg/kg/d)-1	Source[2]	EPA Weight of Evidence
Diallate			C			B2
Diaminotoluene (mixed)			B2			B2
1,2,7,8-Dibenzopyrene			B2			B2
Dibenz(a,h)anthracene			B2			B2
1,2-Dibromo-3-chloropropane			B2			B2
Dibutylnitrosamine	5.40E+00	CAG	B2			B2
3,3'-Dichlorobenzidine	1.70E+00	CAG	B2			B2
1,2-Dichloroethane (EDC)	9.10E-02	HEA	B2	3.50E-02	HEA	B2
1,1-Dichloroethylene	5.80E-01	HEA	C	1.16E+00	HEA	C
Dichloromethane	7.50E-03	HEA	B2	1.43E-02	HEA	B2
Dieldrin	3.00E+01	CAG	B2			B2
Diepoxybutane			B2			B2
Diethanolnitrosamine			B2			B2
Diethyl Arsine			D			D
1,2-Diethylhydrazine			B2			B2
Diethylnitrosamine	4.40E+01	CAG	B2			B2
Diethylstilbestrol (DES)			A			A
Dihydrosafrole			B2			B2
3,3'-Dimethoxybenzidine			B2			B2
Dimethyl Sulfate			B2			B2
Dimethylaminoazobenzene			B2			B2
7,12-Dimethylbenz(a)anthracene			B2			B2
3,3'-Dimethylbenzidine			B2			B2
Dimethylcarbamoyl Chloride			B2			B2
1,1-Dimethylhydrazine			B2			B2
1,2-Dimethylhydrazine			B2			B2
Dimethylnitrosamine	2.60E+01	CAG	B2			B2
Dinitrotoluene (mixed)			B2			B2
2,4-Dinitrotoluene	3.10E-01	CAG	B2			B2
2,6-Dinitrotoluene			C			C
1,4-Dioxane			B2			B2
1,2-Diphenylhydrazine	7.70E-01	CAG	B1			B2
Dipropylnitrosamine			B2			B2
Epichlorohydrin	9.90E-04	CAG	B2			B2
Ethyl-4,4'-dichlorobenzilate			B2			B2
Ethylene Dibromide (EDB)	4.10E+01	CAG	B2			B2

EXHIBIT C-4
(Continued)

TOXICITY DATA FOR POTENTIAL CARCINOGENIC EFFECTS -- RISK CHARACTERIZATION

Chemical Name	Oral Route			Inhalation Route		
	Potency Factor (PF) (mg/kg/d)-1	Source$^{a/}$	EPA Weight of Evidence	Potency Factor (PF) (mg/kg/d)-1	Source$^{a/}$	EPA Weight of Evidence
Ethylene Oxide			B1/B2	3.50E-01	CAG	B1/B2
Ethylenethiourea			B2			B2
Ethyl Methanesulfonate			B2			B2
1-Ethyl-nitrosourea	3.30E+01	CAG	B2			B2
Formaldehyde			B2			B2
Glycidaldehyde			B2			B2
Heptachlor	3.40E+00	CAG	B2			B2
Heptachlor Epoxide	2.60E+00	CAG	B2			B2
Hexachlorobenzene	1.69E+00	HEA	B2			B2
Hexachlorobutadiene	7.75E-03	HEA	C			C
alpha-Hexachlorocyclohexane (HCCH)	1.10E+01	CAG	B2			B2
beta-HCCH	1.80E+00	CAG	C			C
gamma-HCCH (Lindane)	1.33E+00	HEA	B2/C			B2/C
Hexachloroethane	1.40E-02	CAG	C			C
Hydrazine			B2			B2
Indeno(1,2,3-cd)pyrene			C			C
Iodomethane			C			C
Isosafrole			B2			C
Kepone			B2			B2
Lasiocarpine			B2			B2
Melphalan			B1			B1
Methyl Chloride			C			C
3-Methylcholanthrene			B2			B2
4,4'-Methylene-bis-2-chloroaniline			B2			B2
Methylnitrosourea	3.00E+02	CAG	B2			B2
Methylnitrosourethane			B2			B2
Methylthiouracil			B2			B2
Methylvinylnitrosamine			B2			B2
N-Methyl-N'-nitro-N-nitrosoguanadine			B2			B2
Mitomycin C			B2			B2
1-Napthylamine			C			C
2-Napthylamine			A			A
Nickel and Compounds	NA		A	1.19E+00	HEA	A
N-Nitrosopiperidine			B2			B2
N-Nitrosopyrrolidine	2.10E+00	CAG	B2			B2
5-Nitro-o-toluidine			C			C

EXHIBIT C-4
(Continued)

TOXICITY DATA FOR POTENTIAL CARCINOGENIC EFFECTS -- RISK CHARACTERIZATION

	Oral Route			Inhalation Route		
Chemical Name	Potency Factor (PF) (mg/kg/d)-1	Source[2]	EPA Weight of Evidence	Potency Factor (PF) (mg/kg/d)-1	Source[2]	EPA Weight of Evidence
Pentachloronitrobenzene			C			C
Pentachlorophenol			D			D
Phenacetin			B2			B2
Polychlorinated Biphenyls (PCBs)	4.34E+00	HEA	B2			B2
Polynuclear Aromatic Hydrocarbons	1.15E+01	HEA		6.11E+00	HEA	
Propane Sultone			B2			B2
1,2-Propylenimine			B2			B2
Saccharin			C			C
Safrole			B2			B2
Streptozocin			B2			B2
2,3,7,8-TCDD (Dioxin)	1.56E+05	HEA	B2			B2
1,1,1,2-Tetrachloroethane			B2			C
1,1,2,2-Tetrachloroethane	2.00E-01	HEA	C			C
Tetrachloroethylene	5.10E-02	HEA	B2	1.70E-03	HEA	B2
Thioacetamide			B2			B2
Thiourea			B2			B2
o-Toluidine hydrochloride			B2			B2
Toxaphene	1.10E+00	CAG	B2			B2
1,1,2-Trichloroethane	5.73E-02	HEA	C			C
Trichloroethylene	1.10E-02	HEA	B2	4.60E-03	HEA	B2
2,4,6-Trichlorophenol	1.98E-02	HEA	B2			B2
Tris(2,3-dibromopropyl)phosphate			B2			B2
Trypan Blue			B2			B2
Uracil Mustard			B2			B2
Urethane			B2			B2
Vinyl Chloride	2.30E+00	HEA	A	2.50E-02	HEA	A

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[1] The list of chemicals presented in this exhibit is based on EPA's Reportable Quantities Analysis and should not be considered an all-inclusive list of suspected carcinogens. Refer to Exhibit C-3 for toxicity constants for indicator selection for the chemicals listed here.

[2] Sources for Exhibit C-4:

HEA = Health Effects Assessment, prepared by the Environmental Criteria and Assessment Office, U.S. EPA, Cincinnati, Ohio, 1985 (updated in May 1986).

CAG = Evaluation by Carcinogen Assessment Group, U.S. EPA, Washington, D.C., 1985.

Date Prepared: October 1, 1986

EXHIBIT C-5

TOXICITY DATA FOR NONCARCINOGENIC EFFECTS -- SELECTION OF INDICATOR CHEMICALS ONLY [1]

	Oral Route				Inhalation Route		
	Minimum Effective Dose (MED) mg/day	RVe	Toxicity Constant Water (wTn) l/mg	Toxicity Constant Soil (sTn) kg/mg	Minimum Effective Dose (MED) mg/day	RVe	Air Toxicity Constant (aTn) m3/kg
Chemical Name							
Acenaphthene @							
Acenaphthylene @							
Acetone							
Acetonitrile					1.23E+02	8	1.31E+00
2-Acetylaminofluorene @							
Acrylic Acid							
Acrylonitrile @	2.99E+01	9	6.02E-01	3.01E-05	4.34E+01	10	4.61E+00
Aflatoxin B1 @							
Aldicarb							
Aldrin @							
Allyl Alcohol	3.54E+00 *	6	3.39E+00	1.69E-04	3.54E+00	6	3.39E+01
Aluminum Phosphide							
4-Aminobiphenyl @							
Amitrole @							
Ammonia	8.80E-01	3	6.82E+00	3.41E-04	4.25E+01	5	2.35E+00
Anthracene @							
Antimony and Compounds	4.60E+00	10	4.35E+00	2.17E-04	7.00E-01	8	2.29E+02
Arsenic and Compounds @	1.00E+00	9	1.80E+01	9.00E-04	1.00E+00 *	9	1.80E+02
Asbestos @					2.70E-02	10	7.41E+03
Auramine @							
Azaserine @							
Aziridine @							
Barium and Compounds	4.90E+00	10	4.08E+00	2.04E-04	4.90E+00 *	10	4.08E+01
Benefin							
Benzene @	8.55E+01	5	1.17E-01	5.85E-06	1.70E+00	10	1.18E+02
Benzidine @	2.24E+01	8	7.14E-01	3.57E-05	1.19E+01	7	1.18E+01
Benz(a)anthracene @							
Benz(c)acridine @							
Benzo(a)pyrene @	6.00E-01	8	2.67E+01	1.33E-03	6.28E+00	6	1.91E+01
Benzo(b)fluoranthene @							
Benzo(ghi)perylene @							
Benzo(k)fluoranthene @							
Benzotrichloride @							
Benzyl Chloride @							
Beryllium and Compounds @					1.10E-02	8	1.45E+04
1,1-Biphenyl							
Bis(2-chloroethyl)ether @							
Bis(2-chloroisopropyl)ether	7.43E+02	10	2.69E-02	1.35E-06	7.43E+02 *	10	2.69E-01
Bis(chloromethyl)ether @							
Bis(2-ethylhexyl)phthalate (DEHP) @							
Bromomethane							

Date Prepared: October 1, 1986

EXHIBIT C-5
(Continued)

TOXICITY DATA FOR NONCARCINOGENIC EFFECTS -- SELECTION OF INDICATOR CHEMICALS ONLY

	Oral Route				Inhalation Route		
	Minimum Effective Dose (MED)		Toxicity Constant		Minimum Effective Dose (MED)		Air Toxicity Constant (aTn)
Chemical Name	mg/day	RVe	Water (wTn) l/mg	Soil (sTn) kg/mg	mg/day	RVe	m3/kg
Bromoxynil Octanoate							
1,3-Butadiene	2.39E+00	4	3.35E+00	1.67E-04	2.39E+00 *	4	3.35E+01
n-Butanol							
Butylphthalyl Butylglycolate							
Cacodylic Acid @							
Cadmium and Compounds @	4.49E+00	10	4.45E+00	2.23E-04	4.46E-01	8	3.59E+02
Captan	9.85E+02	10	2.03E-02	1.02E-06	9.85E+02 *	10	2.03E-01
Carbaryl							
Carbon Disulfide	3.30E+01 *	7	4.24E-01	2.12E-05	3.30E+01	7	4.24E+00
Carbon Tetrachloride @	6.30E+01 *	10	3.17E-01	1.59E-05	6.30E+01	10	3.17E+00
Chlordane @							
Chlorobenzene	5.60E+01	4	1.43E-01	7.14E-06	7.18E+01	1	2.79E-01
Chlorobenzilate @							
Chlorodibromomethane	6.60E+00	6	1.82E+00	9.09E-05	6.60E+00 *	6	1.82E+01
Chloroform @							
Chloromethyl Methyl Ether @					5.90E+00	7	2.37E+01
4-Chloro-o-toluidine Hydrochloride@							
Chromium III and Compounds							
Chromium VI and Compounds @					6.40E+00	8	2.50E+01
Chrysene @							
Copper and Compounds	1.40E+01	5	7.14E-01	3.57E-05	1.40E+01 *	5	7.14E+00
Creosote @							
Cresol	1.34E+00 *	4	5.97E+00	2.99E-04	1.34E+00	4	5.97E+01
Crotonaldehyde							
Cyanides (n.o.s.) [2]							
-- Barium Cyanide							
-- Calcium Cyanide							
-- Cyanogen							
-- Cyanogen Chloride							
-- Copper Cyanide							
-- Hydrogen Cyanide							
-- Nickel Cyanide							
-- Potassium Cyanide							
-- Potassium Silver Cyanide							
-- Silver Cyanide							
-- Sodium Cyanide							
-- Zinc Cyanide							
Cyclophosphamide @							
Dalapon							
DDD @							

Date Prepared: October 1, 1986

EXHIBIT C-5
(Continued)

TOXICITY DATA FOR NONCARCINOGENIC EFFECTS
-- SELECTION OF INDICATOR CHEMICALS ONLY

	Oral Route				Inhalation Route		
	Minimum Effective Dose (MED)		Toxicity Constant		Minimum Effective Dose (MED)		Air Toxicity Constant (aTn)
Chemical Name	mg/day	RVe	Water (wTn) 1/mg	Soil (sTn) kg/mg	mg/day	RVe	m3/kg
DDE @							
DDT @							
Decabromodiphenyl Ether							
Diallate @							
2,4-Diaminotoluene @							
1,2,7,8-Dibenzopyrene @							
Dibenz(a,h)anthracene @							
1,2-Dibromo-3-chloropropane @							
Dibutylnitrosamine @							
Dibutyl Phthalate	4.20E+02	8	3.81E-02	1.90E-06	4.20E+02 *	8	3.81E-01
1,2-Dichlorobenzene	1.54E+02	4	5.19E-02	2.60E-06	2.77E+02 *	5	3.61E-01
1,3-Dichlorobenzene	1.54E+02	4	5.19E-02	2.60E-06	2.77E+02	5	3.61E-01
1,4-Dichlorobenzene	1.54E+02	4	5.19E-02	2.60E-06	2.77E+02	5	3.61E-01
3,3'-Dichlorobenzidine @							
Dichlorodifluoromethane							
1,1-Dichloroethane	5.42E+02 *	7	2.58E-02	1.29E-06	5.42E+02	7	2.58E-01
1,2-Dichloroethane (EDC) @	1.14E+03	10	1.76E-02	8.80E-07	1.45E+02	8	1.10E+00
1,1-Dichloroethylene @	3.77E+01	7	3.71E-01	1.86E-05	1.77E+01	5	5.65E+00
1,2-Dichloroethylene (cis)	1.89E+02 *	5	5.29E-02	2.65E-06	1.89E+02	5	5.29E-01
1,2-Dichloroethylene (trans)	1.89E+02 *	5	5.29E-02	2.65E-06	1.89E+02	5	5.29E-01
Dichloromethane @	2.18E+04	10	9.20E-04	4.60E-08	2.18E+04 *	10	9.20E-03
2,4-Dichlorophenol	1.21E+02	5	8.26E-02	4.13E-06	1.21E+02 *	5	8.26E-01
2,4-Dichlorophenoxyacetic Acid (2,4-D)	1.29E+02	8	1.24E-01	6.20E-06	1.29E+02 *	8	1.24E+00
4-(2,4-Dichlorophenoxy)butyric Acid (2,4-DB)							
Dichlorophenylarsine @							
1,2-Dichloropropane	2.00E+02 *	10	1.00E-01	5.00E-06	2.00E+02	10	1.00E+00
1,3-Dichloropropene	6.00E-01	1	3.33E+00	1.67E-04	3.24E+00	5	3.09E-01
Dieldrin @							
Diepoxybutane @							
Diethanolnitrosamine @							
Diethyl Arsine @							
1,2-Diethylhydrazine @							
Diethylnitrosamine @							
Diethyl Phthalate	2.99E+04	4	2.67E-04	1.34E-08	2.99E+04 *	4	2.67E-03
Diethylstilbestrol (DES) @							
Dihydrosafrole @							
Dimethoate							
3,3'-Dimethoxybenzidine @							

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EXHIBIT C-5
(Continued)

TOXICITY DATA FOR NONCARCINOGENIC EFFECTS -- SELECTION OF INDICATOR CHEMICALS ONLY

	Oral Route				Inhalation Route		
			Toxicity Constant				
Chemical Name	Minimum Effective Dose (MED) mg/day	RVe	Water (wTn) l/mg	Soil (sTn) kg/mg	Minimum Effective Dose (MED) mg/day	RVe	Air Toxicity Constant (aTn) m3/kg
Dimethylamine	3.70E+01 *	6	3.24E-01	1.62E-05	3.70E+01	6	3.24E+00
Dimethyl Sulfate @							
Dimethyl Terephthalate							
Dimethylaminoazobenzene @							
7,12-Dimethylbenz(a)anthracene @							
3,3'-Dimethylbenzidine @							
Dimethylcarbamoyl Chloride @							
1,1-Dimethylhydrazine @							
1,2-Dimethylhydrazine @							
Dimethylnitrosamine @							
1,3-Dinitrobenzene	1.35E+00	6	8.89E+00	4.44E-04	1.35E+00 *	6	8.89E+01
4,6-Dinitro-o-cresol	2.45E+00	8	6.53E+00	3.27E-04	2.45E+00 *	8	6.53E+01
2,4-Dinitrophenol	1.40E+01	8	1.14E+00	5.71E-05	1.40E+01 *	8	1.14E+01
2,3-Dinitrotoluene @							
2,4-Dinitrotoluene @	2.05E+01	9	8.78E-01	4.39E-05	2.05E+01 *	9	8.78E+00
2,5-Dinitrotoluene @							
2,6-Dinitrotoluene @	2.99E+01	9	6.02E-01	3.01E-05	2.99E+01 *	9	6.02E+00
3,4-Dinitrotoluene @							
Dinoseb							
1,4-Dioxane @							
N,N-Diphenylamine @							
1,2-Diphenylhydrazine @	5.98E+01	10	3.34E-01	1.67E-05	5.98E+01 *	10	3.34E+00
Dipropylnitrosamine @							
Disulfoton							
Endosulfan							
Epichlorohydrin @							
Ethanol	2.40E+04	10	8.33E-04	4.17E-08	2.40E+04 *	10	8.33E-03
Ethyl Acetate							
Ethyl Methanesulfonate @							
Ethylbenzene	7.24E+02 *	4	1.10E-02	5.52E-07	7.24E+02	4	1.10E-01
Ethyl-4,4'-dichlorobenzilate @							
Ethylene Dibromide (EDB) @							
Ethylene Oxide @							
Ethylenethiourea @							
1-Ethyl-nitrosourea @							
Ethylphthalyl Ethyl Glycolate							
Ferric Dextran @							
Fluoranthene @							
Fluorene @							
Fluorides	8.01E+00	5	1.25E+00	6.24E-05			

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EXHIBIT C-5
(Continued)

TOXICITY DATA FOR NONCARCINOGENIC EFFECTS -- SELECTION OF INDICATOR CHEMICALS ONLY

	Oral Route				Inhalation Route		
			Toxicity Constant				
Chemical Name	Minimum Effective Dose (MED) mg/day	RVe	Water (wTn) 1/mg	Soil (sTn) kg/mg	Minimum Effective Dose (MED) mg/day	RVe	Air Toxicity Constant (aTn) m3/kg
Fluridone							
Formaldehyde					1.00E+00	7	1.40E+02
Formic Acid							
Furan							
Glycidaldehyde @							
Glycol Ethers (n.o.s.)							
-- Diethylene Glycol, Monoethyl Ether							
-- 2-Ethoxyethanol							
-- Ethylene Glycol, Monobutyl Ether							
-- 2-Methoxyethanol							
-- Propylene Glycol, Monoethyl Ether							
-- Propylene Glycol, Monomethyl Ether							
Heptachlor @							
Heptachlor Epoxide @							
Hexachlorobenzene @	5.00E+01	10	4.00E-01	2.00E-05	5.00E+01 *	10	4.00E+00
Hexachlorobutadiene @							
Hexachlorocyclopentadiene							
alpha-Hexachlorocyclohexane (HCCH)@							
beta-HCCH @							
gamma-HCCH (Lindane) @							
delta-HCCH @							
Hexachloroethane @	1.81E+03	6	6.62E-03	3.31E-07	4.49E+02	10	4.45E-01
Hexachlorophene	2.99E+01	9	6.02E-01	3.01E-05	2.99E+01 *	9	6.02E+00
Hydrazine @							
Hydrogen Sulfide							
Indeno(1,2,3-cd)pyrene @							
Iodomethane @							
Iron and Compounds							
Isobutanol							
Isoprene	5.50E+02 *	4	1.45E-02	7.27E-07	5.50E+02	4	1.45E-01
Isosafrole @							
Isophorone							
Isopropalin							
Kepone @							
Lasiocarpine @							
Lead and Compounds (Inorganic)	2.24E+01	10	8.93E-01	4.46E-05	2.24E+01 *	10	8.93E+00
Linuron							
Malathion							
Manganese and Compounds							
Melphalan @							

EXHIBIT C-5
(Continued)

TOXICITY DATA FOR NONCARCINOGENIC EFFECTS -- SELECTION OF INDICATOR CHEMICALS ONLY

	Oral Route				Inhalation Route		
			Toxicity Constant				
Chemical Name	Minimum Effective Dose (MED) mg/day	RVe	Water (wTn) 1/mg	Soil (sTn) kg/mg	Minimum Effective Dose (MED) mg/day	RVe	Air Toxicity Constant (aTn) m3/kg
Mercury and Compounds (Alkyl)							
Mercury and Compounds (Inorganic)	7.60E-01	7	1.84E+01	9.21E-04	8.60E-01	8	1.86E+02
Mercury Fulminate							
Methanol							
Methyl Chloride	2.21E+02 *	10	9.05E-02	4.52E-06	2.21E+02	10	9.05E-01
Methyl Ethyl Ketone	2.58E+03 *	10	7.75E-03	3.87E-07	2.58E+03	10	7.75E-02
Methyl Ethyl Ketone Peroxide							
Methyl Isobutyl Ketone							
Methyl Methacrylate	1.76E+03	4	4.55E-03	2.28E-07	1.22E+02	7	1.15E+00
Methyl Parathion	1.07E+01	10	1.87E+00	9.35E-05	2.40E-02	5	4.17E+03
2-Methyl-4-Chlorophenoxyacetic Acid							
2(2-Methyl-4-Chlorophenoxy) propionic Acid							
3-Methylcholanthrene @							
4,4'-Methylene-bis-2-chloroaniline@							
Methylnitrosourea @							
Methylthiouracil @							
Methylvinylnitrosamine @							
N-Methyl-N'-nitro-N-nitrosoguanadine@							
Mitomycin C @							
Mustard Gas @							
1-Napthylamine @							
2-Napthylamine @							
Nickel and Compounds @	4.70E+00	10	4.26E+00	2.13E-04	1.27E+00	10	1.57E+02
Nitric Oxide							
Nitrobenzene							
Nitrogen Dioxide							
Nitrosomethylurethane @							
N-Nitrosopiperidine @							
N-Nitrosopyrrolidine @							
5-Nitro-o-toluidine @							
Osmium Tetroxide							
Pentachlorobenzene	8.62E+02	10	2.32E-02	1.16E-06	8.62E+02 *	10	2.32E-01
Pentachloronitrobenzene @	2.20E-01	6	5.45E+01	2.73E-03	2.20E-01 *	6	5.45E+02
Pentachlorophenol							
Phenacetin @							
Phenanthrene @							
Phenobarbital @							
Phenol	5.98E+01	3	1.00E-01	5.02E-06	8.02E+01	10	2.49E+00
Phenylalanine Mustard @							

EXHIBIT C-5
(Continued)

TOXICITY DATA FOR NONCARCINOGENIC EFFECTS -- SELECTION OF INDICATOR CHEMICALS ONLY

	Oral Route				Inhalation Route		
			Toxicity Constant				
Chemical Name	Minimum Effective Dose (MED) mg/day	RVe	Water (wTn) l/mg	Soil (sTn) kg/mg	Minimum Effective Dose (MED) mg/day	RVe	Air Toxicity Constant (aTn) m3/kg
m-Phenylenediamine							
Phenyl Mercuric Acetate							
Phosphine							
Polychlorinated Biphenyls (PCBs) @							
Propane Sultone @							
Propylenimine @							
Pyrene @							
Pyridine							
Saccharin @							
Safrole @							
Selenium and Compounds (n.o.s.)	1.90E-01	10	1.05E+02	5.26E-03	1.90E-01 *	10	1.05E+03
-- Selenious Acid							
-- Selenourea							
-- Thallium Selenite							
Silver and Compounds	1.00E-01	1	2.00E+01	1.00E-03	1.00E-01 *	1	2.00E+02
Sodium Diethyldithiocarbamate							
Streptozocin @							
Strychnine							
Styrene							
1,2,4,5-Tetrachlorobenzene	2.05E+01	1	9.76E-02	4.88E-06	2.05E+01 *	1	9.76E-01
2,3,7,8-TCDD (Dioxin) @							
1,1,1,2-Tetrachloroethane @							
1,1,2,2-Tetrachloroethane @	2.20E+01 *	5	4.55E-01	2.27E-05	2.20E+01	5	4.55E-00
Tetrachloroethylene @	1.46E+03	7	9.62E-03	4.81E-07	7.27E+03	10	2.75E-02
2,3,4,6-Tetrachlorophenol	1.07E+01	8	1.50E+00	7.48E-05	1.07E+01 *	8	1.50E-01
2,3,5,6-Tetrachloroterephthalate Acid (DCPA)							
Tetraethyl Lead @	1.40E-03	5	7.14E+03	3.57E-01	2.50E+00	5	4.00E-01
Thallium and Compounds (n.o.s.)							
-- Thallium Acetate							
-- Thallium Carbonate							
-- Thallium Chloride							
-- Thallium Nitrate							
-- Thallic Oxide							
-- Thallium Sulfate							
Thioacetamide @							
Thiourea @							
o-Tolidine @							
Toluene	2.69E+03 *	7	5.20E-03	2.60E-07	2.69E+03	7	5.20E-02
o-Toluidine Hydrochloride @							

Date Prepared: October 1, 1986

EXHIBIT C-5
(Continued)

TOXICITY DATA FOR NONCARCINOGENIC EFFECTS -- SELECTION OF INDICATOR CHEMICALS ONLY

	Oral Route				Inhalation Route		
	Minimum Effective Dose (MED)		Toxicity Constant		Minimum Effective Dose (MED)		Air Toxicity Constant (aTn)
Chemical Name	mg/day	RVe	Water (wTn) 1/mg	Soil (sTn) kg/mg	mg/day	RVe	m3/kg
Toxaphene @							
Tribromomethane (Bromoform)	6.60E+00	6	1.82E+00	9.09E-05	6.60E+00 *	6	1.82E+01
1,2,4-Trichlorobenzene	3.73E+01	4	2.14E-01	1.07E-05	1.32E+01	1	1.52E+00
1,1,1-Trichloroethane	5.45E+03 *	2	7.33E-04	3.67E-08	5.45E+03	2	7.33E-03
1,1,2-Trichloroethane @							
Trichloroethylene @	9.50E+00	5	1.05E+00	5.26E-05	2.70E+00	4	2.96E+01
Trichlorofon	4.52E+01	10	4.42E-01	2.21E-05	4.52E+01 *	10	4.42E+00
Trichloromonofluoromethane							
2,4,5-Trichlorophenol	1.18E+02	6	1.02E-01	5.10E-06	1.18E+02 *	6	1.02E+00
2,4,6-Trichlorophenol @							
2,4,5-Trichlorophenoxyacetic Acid							
1,2,3-Trichloropropane							
1,1,2-Trichloro-1,2,2-trifluoroethane							
Tris(2,3-dibromopropyl)phosphate @							
Trinitrotoluene (TNT)							
Trypan Blue @							
Uracil Mustard @							
Uranium and Compounds	1.70E+00	6	7.06E+00	3.53E-04	1.70E+00 *	6	7.06E+01
Urethane @							
Vanadium and Compounds	1.40E+01	1	1.43E-01	7.14E-06	1.40E+01 *	1	1.43E+00
Vinyl Chloride @	2.28E+02 *	10	8.77E-02	4.39E-06	2.28E+02	10	8.77E-01
Warfarin							
o-Xylene							
m-Xylene							
p-Xylene							
Xylenes (mixed)							
Zinc and Compounds	1.50E+02	8	1.07E-01	5.33E-06	1.50E+02 *	8	1.07E-00
-- Zinc Phosphide							
Zineb							

@ Potential carcinogenic effects also. See Exhibits C-3 and C-4.

* MED and RVe values marked with an asterisk are based on values for the other exposure route.

[1] Refer to Exhibit C-6 for toxicity data for risk characterization for the chemicals listed here.

[2] N.O.S. = not otherwise specified.

Date Prepared: October 1, 1986

EXHIBIT C-6

TOXICITY DATA FOR NONCARCINOGENIC EFFECTS -- RISK CHARACTERIZATION [1]

Chemical Name	Oral Route Acceptable Intake Subchron (AIS) --mg/kg/day--	Oral Route Acceptable Intake Chronic (AIC) --mg/kg/day--	Oral Route Source[2]	Inhalation Route Acceptable Intake Subchron (AIS) --mg/kg/day--	Inhalation Route Acceptable Intake Chronic (AIC) --mg/kg/day--	Inhalation Route Source[2]
Acenaphthene @						
Acenaphthylene @						
Acetone		1.00E-01	RfD	3.00E+01	3.00E+00	HEA
Acetonitrile						
2-Acetylaminofluorene @						
Acrylic Acid		8.00E-02	RfD[3]			
Acrylonitrile @						
Aflatoxin B1 @						
Aldicarb		1.00E-02	RfD			
Aldrin @		3.00E-05	RfD			
Allyl Alcohol		5.00E-03	RfD			
Aluminum Phosphide		4.00E-04	RfD			
4-Aminobiphenyl @						
Amitrole @						
Ammonia						
Anthracene @						
Antimony and Compounds		4.00E-04	RfD			
Arsenic and Compounds @						
Asbestos @						
Auramine @						
Azaserine @						
Aziridine @						
Barium and Compounds		5.10E-02	HEA	1.4E-3(T)[4]	1.40E-04	HEA
Benefin		3.00E-01	RfD			
Benzene @						
Benzidine @						
Benz(a)anthracene @						
Benz(c)acridine @						
Benzo(a)pyrene @						
Benzo(b)fluoranthene @						
Benzo(ghi)perylene @						
Benzo(k)fluoranthene @						
Benzotrichloride @						
Benzyl Chloride @						
Beryllium and Compounds @		5.00E-04	RfD			
1,1-Biphenyl		5.00E-02	RfD			
Bis(2-chloroethyl)ether @						
Bis(2-chloroisopropyl)ether						
Bis(chloromethyl)ether @						
Bis(2-ethylhexyl)phthalate (DEHP) @		2.00E-02	RfD			
Bromomethane		4.00E-04	RfD			
Bromoxynil Octanoate		3.00E-02	RfD			
1,3-Butadiene						

Date Prepared: October 1, 1986

EXHIBIT C-6
(Continued)

TOXICITY DATA FOR NONCARCINOGENIC EFFECTS -- RISK CHARACTERIZATION

	Oral Route			Inhalation Route		
	Acceptable Intake			Acceptable Intake		
Chemical Name	Subchron (AIS) --mg/kg/day--	Chronic (AIC)	Source	Subchron (AIS) --mg/kg/day--	Chronic (AIC)	Source
n-Butanol		1.00E-01	RfD			
Butylpthalyl Butylglycolate		1.00E+00	RfD			
Cacodylic Acid @		1.00E-02	RfD			
Cadmium and Compounds @		2.90E-04	HEA			
Captan						
Carbaryl		1.00E-01	RfD			
Carbon Disulfide		1.00E-01	RfD			
Carbon Tetrachloride @						
Chlordane @		5.00E-05	RfD			
Chlorobenzene	2.70E-01	2.70E-02	HEA	5.30E-02	5.70E-03	HEA
Chlorobenzilate @						
Chlorodibromomethane						
Chloroform @		1.00E-02	RfD			
Chloromethyl Methyl Ether @						
4-Chloro-o-toluidine Hydrochloride@						
Chromium III and Compounds	1.40E+01	1.00E+00	RfD		5.10E-03	HEA
Chromium VI and Compounds @	2.50E-02	5.00E-03	HEA			
Chrysene @						
Copper and Compounds	3.70E-02	3.70E-02	HEA		1.00E-02	HEA
Creosote @						
Cresol		5.00E-02	RfD		1.00E-01	HEA
Crotonaldehyde		1.00E-02	RfD			
Cyanides (n.o.s.) [5]		2.00E-02	RfD			
-- Barium Cyanide		7.00E-02	RfD			
-- Calcium Cyanide		4.00E-02	RfD			
-- Cyanogen		4.00E-02	RfD			
-- Cyanogen Chloride		5.00E-02	RfD			
-- Copper Cyanide		7.00E-02	RfD			
-- Hydrogen Cyanide		2.00E-02	RfD			
-- Nickel Cyanide		2.00E-02	RfD			
-- Potassium Cyanide		5.00E-02	RfD			
-- Potassium Silver Cyanide		2.00E-01	RfD			
-- Silver Cyanide		1.00E-01	RfD			
-- Sodium Cyanide		4.00E-02	RfD			
-- Zinc Cyanide		5.00E-02	RfD			
Cyclophosphamide @						
Dalapon		8.00E-02	RfD			
DDD @						
DDE @						
DDT @		5.00E-04	RfD			
Decabromodiphenyl Ether		1.00E-02	RfD			
Diallate @						

EXHIBIT C-6
(Continued)

TOXICITY DATA FOR NONCARCINOGENIC EFFECTS -- RISK CHARACTERIZATION

	Oral Route			Inhalation Route		
	Acceptable Intake			Acceptable Intake		
Chemical Name	Subchron (AIS) --mg/kg/day--	Chronic (AIC)	Source	Subchron (AIS) --mg/kg/day--	Chronic (AIC)	Source
2,4-Diaminotoluene @						
1,2,7,8-Dibenzopyrene @						
Dibenz(a,h)anthracene @						
1,2-Dibromo-3-chloropropane @						
Dibutylnitrosamine @						
Dibutyl Phthalate		1.00E-01	RfD			
1,2-Dichlorobenzene						
1,3-Dichlorobenzene						
1,4-Dichlorobenzene						
3,3'-Dichlorobenzidine @						
Dichlorodifluoromethane		2.00E-01	RfD			
1,1-Dichloroethane	1.20E+00	1.20E-01	HEA	1.38E+00	1.38E-01	HEA
1,2-Dichloroethane (EDC) @						
1,1-Dichloroethylene @		9.00E-03	RfD			
1,2-Dichloroethylene (cis)						
1,2-Dichloroethylene (trans)						
Dichloromethane @		6.00E-02	RfD			
2,4-Dichlorophenol		3.00E-03	RfD			
2,4-Dichlorophenoxyacetic Acid (2,4-D)						
4-(2,4-Dichlorophenoxy)butyric Acid (2,4-DB)		8.00E-03	RfD			
Dichlorophenylarsine @						
1,2-Dichloropropane						
1,3-Dichloropropene						
Dieldrin @						
Diepoxybutane @						
Diethanolnitrosamine @						
Diethyl Arsine @						
1,2-Diethylhydrazine @						
Diethylnitrosamine @						
Diethyl Phthalate		1.30E+01	RfD			
Diethylstilbestrol (DES) @						
Dihydrosafrole @						
Dimethoate		2.00E-02	RfD			
3,3'-Dimethoxybenzidine @						
Dimethylamine						
Dimethyl Sulfate @						
Dimethyl Terephthalate		1.00E-01	RfD			
Dimethylaminoazobenzene @						
7,12-Dimethylbenz(a)anthracene @						
3,3'-Dimethylbenzidine @						

EXHIBIT C-6
(Continued)

TOXICITY DATA FOR NONCARCINOGENIC EFFECTS -- RISK CHARACTERIZATION

	Oral Route			Inhalation Route		
	Acceptable Intake			Acceptable Intake		
Chemical Name	Subchron (AIS) --mg/kg/day--	Chronic (AIC)	Source	Subchron (AIS) --mg/kg/day--	Chronic (AIC)	Source
Dimethylcarbamoyl Chloride @						
1,1-Dimethylhydrazine @						
1,2-Dimethylhydrazine @						
Dimethylnitrosamine @						
1,3-Dinitrobenzene						
4,6-Dinitro-o-cresol						
2,4-Dinitrophenol		2.00E-03	RfD			
2,3-Dinitrotoluene @						
2,4-Dinitrotoluene @						
2,5-Dinitrotoluene @						
2,6-Dinitrotoluene @						
3,4-Dinitrotoluene @						
Dinoseb		1.00E-03	RfD			
1,4-Dioxane @						
N,N-Diphenylamine @						
1,2-Diphenylhydrazine @						
Dipropylnitrosamine @						
Disulfoton		4.00E-03	RfD			
Endosulfan		1.50E-05	RfD			
Epichlorohydrin @		2.00E-03	RfD			
Ethanol						
Ethyl Acetate		9.00E-01	RfD			
Ethyl Methanesulfonate @						
Ethylbenzene	9.70E-01	1.00E-01	RfD			
Ethyl-4,4'-dichlorobenzilate @						
Ethylene Dibromide (EDB) @						
Ethylene Oxide @						
Ethylenethiourea @						
1-Ethyl-nitrosourea @						
Ethylphthalyl Ethyl Glycolate		3.00E+00	RfD			
Ferric Dextran @						
Fluoranthene @						
Fluorene @						
Fluorides		6.00E-02	RfD			
Fluridone		8.00E-02	RfD			
Formaldehyde						
Formic Acid		2.00E+00	RfD			
Furan		1.00E-03	RfD			
Glycidaldehyde @						
Glycol Ethers (n.o.s.)						
-- Diethylene Glycol, Monoethyl Ether	5.00E+00	2.00E+00	HEA			

EXHIBIT C-6
(Continued)

TOXICITY DATA FOR NONCARCINOGENIC EFFECTS -- RISK CHARACTERIZATION

	Oral Route			Inhalation Route		
	Acceptable Intake			Acceptable Intake		
Chemical Name	Subchron (AIS) --mg/kg/day--	Chronic (AIC)	Source	Subchron (AIS) --mg/kg/day--	Chronic (AIC)	Source
-- 2-Ethoxyethanol	4.7E-1(T)	3.60E-01	HEA	6.9E-2(T)	5.00E-02	HEA
-- Ethylene Glycol, Monobutyl Ether				1.60E-01	1.60E-02	HEA
-- 2-Methoxyethanol				5.9E-2(T)	2.40E-02	HEA
-- Propylene Glycol, Monoethyl Ether	6.80E+00	6.80E-01	HEA			
-- Propylene Glycol, Monomethyl Ether	6.80E+00	6.80E-01	HEA	4.90E+00	4.90E-01	HEA
Heptachlor @						
Heptachlor Epoxide @		3.00E-05	RfD			
Hexachlorobenzene @						
Hexachlorobutadiene @		2.00E-03	RfD			
Hexachlorocyclopentadiene	7.00E-02	7.00E-03	RfD	2.90E-03	6.60E-05	HEA
alpha-Hexachlorocyclohexane (HCCH)@						
beta-HCCH @						
gamma-HCCH (Lindane) @		3.00E-04	RfD			
delta-HCCH @						
Hexachloroethane @						
Hexachlorophene						
Hydrazine @						
Hydrogen Sulfide		3.00E-03	RfD			
Indeno(1,2,3-cd)pyrene @						
Iodomethane @						
Iron and Compounds					8.60E-03	HEA
Isobutanol		3.00E-01	RfD			
Isoprene						
Isosafrole @						
Isophorone		2.00E-01	RfD			
Isopropalin		3.00E-02	RfD			
Kepone @						
Lasiocarpine @						
Lead and Compounds (Inorganic)		1.40E-03	HEA		4.30E-04	HEA
Linuron						
Malathion		2.00E-02	RfD			
Manganese and Compounds	5.30E-01	2.20E-01	HEA	3.00E-04	3.00E-04	HEA
Melphalan @						
Mercury and Compounds (Alkyl)	2.80E-04	3.00E-04	RfD	1.00E-04	1.00E-04	HEA
Mercury and Compounds (Inorganic)	2.00E-03	2.00E-03	RfD	5.10E-04	5.10E-05	HEA
Mercury Fulminate		3.00E-03	RfD			
Methanol		5.00E-01	RfD			
Methyl Chloride						
Methyl Ethyl Ketone		5.00E-02	RfD	2.20E+00	2.20E-01	HEA

Date Prepared: October 1, 1986

EXHIBIT C-6
(Continued)

TOXICITY DATA FOR NONCARCINOGENIC EFFECTS -- RISK CHARACTERIZATION

	Oral Route			Inhalation Route		
	Acceptable Intake			Acceptable Intake		
Chemical Name	Subchron (AIS) --mg/kg/day--	Chronic (AIC)	Source	Subchron (AIS) --mg/kg/day--	Chronic (AIC)	Source
Methyl Ethyl Ketone Perioxide		8.00E-03	RfD			
Methyl Isobutyl Ketone		5.00E-02	RfD			
Methyl Methacrylate						
Methyl Parathion						
2-Methyl-4-Chlorophenoxyacetic Acid		1.00E-03	RfD			
2(2-Methyl-4-Chlorophenoxy) propionic Acid		3.00E-03	RfD			
3-Methylcholanthrene @						
4,4'-Methylene-bis-2-chloroaniline@						
Methylnitrosourea @						
Methylthiouracil @						
Methylvinylnitrosamine @						
N-Methyl-N'-nitro-N-nitrosoguanadine@						
Mitomycin C @						
Mustard Gas @						
1-Napthylamine @						
2-Napthylamine @						
Nickel and Compounds @	2.00E-02	1.00E-02	HEA			
Nitric Oxide		1.00E-01	RfD			
Nitrobenzene		5.00E-04	RfD			
Nitrogen Dioxide		1.00E+00	RfD			
Nitrosomethylurethane @						
N-Nitrosopiperidine @						
N-Nitrosopyrrolidine @						
5-Nitro-o-toluidine @						
Osmium Tetroxide		1.00E-05	RfD			
Pentachlorobenzene		8.00E-04	RfD			
Pentachloronitrobenzene @		8.00E-03	RfD			
Pentachlorophenol	3.0E-2(T)	3.00E-02	RfD			
Phenacetin @						
Phenanthrene @						
Phenobarbital @						
Phenol	1.00E-01	1.00E-01	RfD	1.90E-01	2.00E-02	HEA
Phenylalanine Mustard @						
m-Phenylenediamine		6.00E-03	RfD			
Phenyl Mercuric Acetate		8.00E-05	RfD			
Phosphine		3.00E-04	RfD			
Polychlorinated Biphenyls (PCBs) @						
Propane Sultone @						
Propylenimine @						
Pyrene @						
Pyridine		2.00E-03	RfD			

EXHIBIT C-6
(Continued)

TOXICITY DATA FOR NONCARCINOGENIC EFFECTS -- RISK CHARACTERIZATION

	Oral Route			Inhalation Route		
	Acceptable Intake			Acceptable Intake		
	Subchron (AIS)	Chronic (AIC)		Subchron (AIS)	Chronic (AIC)	
Chemical Name	--mg/kg/day--		Source	--mg/kg/day--		Source
Saccharin @						
Safrole @						
Selenium and Compounds (n.o.s.)	3.20E-03	3.00E-03	HEA		1.00E-03	HEA
-- Selenious Acid		3.00E-03	RfD			
-- Selenourea		5.00E-03	RfD			
-- Thallium Selenite		5.00E-04	RfD			
Silver and Compounds		3.00E-03	RfD			
Sodium Diethyldithiocarbamate		3.00E-02	RfD			
Streptozocin @						
Strychnine		3.00E-04	RfD			
Styrene		2.00E-01	RfD			
1,2,4,5-Tetrachlorobenzene		3.00E-04	RfD			
2,3,7,8-TCDD (Dioxin) @						
1,1,1,2-Tetrachloroethane @						
1,1,2,2-Tetrachloroethane @						
Tetrachloroethylene @		2.00E-02	RfD			
2,3,4,6-Tetrachlorophenol		1.00E-02	RfD			
2,3,5,6-Tetrachloroterephthalate Acid (DCPA)		5.00E-02	RfD			
Tetraethyl Lead @		1.00E-07	RfD			
Thallium and Compounds (n.o.s.)		4.00E-04	RfD			
-- Thallium Acetate		5.00E-04	RfD			
-- Thallium Carbonate		4.00E-04	RfD			
-- Thallium Chloride		5.00E-04	RfD			
-- Thallium Nitrate		5.00E-04	RfD			
-- Thallic Oxide		4.00E-04	RfD			
-- Thallium Sulfate		5.00E-04	RfD			
Thioacetamide @						
Thiourea @						
o-Tolidine @						
Toluene	4.30E-01	3.00E-01	RfD	1.50E+00	1.50E+00	HEA
o-Toluidine Hydrochloride @						
Toxaphene @						
Tribromomethane (Bromoform)						
1,2,4-Trichlorobenzene		2.00E-02	RfD			
1,1,1-Trichloroethane		5.40E-01	HEA	1.10E+01	6.30E+00	HEA
1,1,2-Trichloroethane @						
Trichloroethylene @						
Trichlorofon						
Trichloromonofluoromethane		3.00E-01	RfD			
2,4,5-Trichlorophenol	1.00E+00	1.00E-01	RfD			
2,4,6-Trichlorophenol @						

Date Prepared: October 1, 1986

EXHIBIT C-6
(Continued)

TOXICITY DATA FOR NONCARCINOGENIC EFFECTS -- RISK CHARACTERIZATION

	Oral Route			Inhalation Route		
	Acceptable Intake			Acceptable Intake		
Chemical Name	Subchron (AIS) --mg/kg/day--	Chronic (AIC)	Source	Subchron (AIS) --mg/kg/day--	Chronic (AIC)	Source
2,4,5-Trichlorophenoxyacetic Acid		3.00E-02	RfD			
1,2,3-Trichloropropane		1.00E-01	RfD			
1,1,2-Trichloro-1,2,2-Trifluoroethane		3.00E+01	RfD			
Tris(2,3-dibromopropyl)phosphate @						
Trinitrotoluene (TNT)		2.00E-04	RfD			
Trypan Blue @						
Uracil Mustard @						
Uranium and Compounds						
Urethane @						
Vanadium and Compounds		2.00E-02	RfD			
Vinyl Chloride @						
Warfarin		3.00E-04	RfD			
o-Xylene	1.00E-01	1.00E-02	HEA	9.6E-1(T)	2.00E-01	HEA
m-Xylene	1.00E-01	1.00E-02	HEA	1.00E+00	2.00E-01	HEA
p-Xylene						
Xylenes (mixed)	1.00E-01	1.00E-02	HEA	6.9E-1(T)	4.00E-01	HEA
Zinc and Compounds	2.10E-01	2.10E-01	HEA	1.00E-01	1.00E-02	HEA
-- Zinc Phosphide		3.00E-04	RfD			
Zineb		5.00E-02	RfD			

@ Potential carcinogenic effects also. See Exhibits C-3 and C-4.

[1] Refer to Exhibit C-5 for toxicity data for indicator selection for the chemicals listed here.

[2] Sources for Exhibit C-6:

RfD = Agency-wide reference dose value, developed by an inter-office work group chaired by the Office of Research and Development, U.S. EPA, Washington, D.C., 1986.

HEA = Health Effects Assessment document, prepared by the Environmental Criteria and Assessment Office, U.S. EPA, Cincinnati, Ohio, 1985 (updated in May 1986).

[3] The RfD values listed here are EPA-verified numbers. All RfD values were derived based on oral exposure; however, in the absence of other more specific data, these values may also be useful in assessing risks of inhalation exposure.

[4] T indicates that teratogenic or fetotoxic effects are the basis for the AIS value listed.

[5] N.O.S. = not otherwise specified.

EXHIBIT C-7

CHEMICALS AND CHEMICAL GROUPS HAVING EPA HEALTH EFFECTS ASSESSMENT (HEA) DOCUMENTS [1]

CHEMICAL	NTIS[2] PB NUMBER
Acetone	86 134277/AS
Arsenic and Compounds	86 134319/AS
Asbestos	86 134608/AS
Barium and Compounds	86 134327/AS
Benzene	86 134483/AS
Benzo(a)pyrene	86 134335/AS
Cadmium and Compounds	86 134491/AS
Carbon Tetrachloride	86 134509/AS
Chlordane	86 134343/AS
Chlorobenzene	86 134517/AS
Chloroform	86 134210/AS
Chromium III and Compounds	86 134467/AS
Chromium VI and Compounds	86 134301/AS
Coal Tars	86 134350/AS
Copper and Compounds	86 134368/AS
Cresol	86 134616/AS
Cyanides	86 134228/AS
DDT	86 134376/AS
1,1-Dichloroethane	86 134384/AS
1,2-Dichloroethane (EDC)	86 134137/AS
1,1-Dichloroethylene	86 134624/AS
1,2-cis-Dichloroethylene	86 134269/AS
1,2-trans-Dichloroethylene	86 134525/AS
Dichloromethane	86 134392/AS
Ethylbenzene	86 134194/AS
Glycol Ethers	86 134632/AS
Hexachlorobenzene	86 134285/AS
Hexachlorobutadiene	86 134640/AS
Hexachlorocyclopentadiene	86 134129/AS
gamma-Hexachlorocyclohexane (Lindane)	86 134673/AS
Iron and Compounds	86 134657/AS
Lead and Compounds (Inorganic)	86 134665/AS
Manganese and Compounds	86 134681/AS
Mercury	86 134533/AS
Methyl Ethyl Ketone	86 134145/AS
Naphthalene	86 134251/AS
Nickel and Compounds	86 134293/AS
Pentachlorophenol	86 134541/AS
Phenanthrene	86 134400/AS
Phenol	86 134186/AS
Polychlorinated Biphenyls (PCBs)	86 134152/AS

EXHIBIT C-7
(Continued)

CHEMICALS AND CHEMICAL GROUPS HAVING EPA HEALTH EFFECTS ASSESSMENT (HEA) DOCUMENTS [1]

CHEMICAL	NTIS[2] PB NUMBER
Polynuclear Aromatic Hydrocarbons	86 134244/AS
Pyrene	86 134418/AS
Selenium and Compounds	86 134699/AS
Sodium Cyanide	86 134236/AS
Sulfuric Acid	86 134426/AS
2,3,7,8-TCDD (Dioxin)	86 134558/AS
1,1,2,2-Tetrachloroethane	86 134434/AS
Tetrachloroethylene	86 134202/AS
Toluene	86 134442/AS
1,1,1-Trichloroethane	86 134160/AS
1,1,2-Trichloroethane	86 134566/AS
Trichloroethylene	86 134574/AS
2,4,5-Trichlorophenol	86 134459/AS
2,4,6-Trichlorophenol	86 134582/AS
Vinyl Chloride	86 134475/AS
Xylene	86 134178/AS
Zinc and Compounds	86 134590/AS
Complete Set of 58 HEAs	86 134111/AS

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[1] As of the date of publication for this manual.

[2] National Technical Information Service.

EXHIBIT C-8

SAFE DRINKING WATER ACT MAXIMUM CONTAMINANT LEVELS (MCLs) a/

CHEMICAL	CONCENTRATION (mg/l)
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chlorophenoxys	
2,4-Dichlorophenoxyacetic acid (2,4-D)	0.1
2,4,5-Trichlorophenoxy-propionic acid (2,4,5-TP)	0.01
Chromium VI (hexavalent)	0.05
Endrin	0.0002
Fluoride	1.4-2.4
Lindane (99% gamma-HCCH)	0.004
Lead	0.05
Mercury	0.002
Methoxychlor	0.1
Nitrate (as N)	10.0
Radionuclides	
Radium-226 and 228	5 pCi/l
Gross alpha activity	15 pCi/l
Tritium	20,000 pCi/l
Strontium-90	8 pCi/l
Other man-made radionuclides	b/
Selenium	0.01
Silver	0.05
Toxaphene	0.005
Trihalomethanes (total) c/	0.1

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a/ EPA has also proposed MCLs for eight volatile organic chemicals: trichloroethylene, carbon tetrachloride, 1,1,1-trichloroethane, vinyl chloride, 1,2-dichloroethane, benzene, 1,1-dichloroethylene, and p-dichlorobenzene (50 Federal Register 46902-46933, November 13, 1985).

b/ Radionuclides in drinking water are limited to activity levels corresponding to a total body or any internal organ dose of 4 millirem/year, summed over all radionuclides present.

c/ Total trihalomethanes refers to the sum concentration of chloroform, bromodichloromethane, dibromochloromethane, and bromoform.

EXHIBIT C-9

SAFE DRINKING WATER ACT MAXIMUM CONTAMINANT LEVEL GOALS (MCLGs) a/

CHEMICAL	CONCENTRATION (mg/l)
Benzene	0
Carbon tetrachloride	0
p-Dichlorobenzene	0.75
1,2-Dichloroethane	0
1,1-Dichloroethylene	0.007
1,1,1-Trichloroethane	0.2
Trichloroethylene	0
Vinyl chloride	0

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a/ EPA has also proposed MCLGs for 40 additional chemicals.

EXHIBIT C-10

EPA AMBIENT WATER QUALITY CRITERIA (WQC) FOR PROTECTION OF HUMAN HEALTH

CHEMICAL	CONCENTRATON a/	
	Aquatic Organisms and Drinking Water	Adjusted for Drinking Water Only b/
Acenaphthene	20 ug/l (Organoleptic) c/	20 ug/l (Organoleptic)
Acrolein	320 ug/l	540 ug/l
Acrylonitrile*	0 (58 ng/l)	0 (63 ng/l)
Aldrin*	0 (0.074 ng/l)	0 (1.2 ng/l)
Antimony*	146 ug/l	146 ug/l
Arsenic*	0 (2.2 ng/l)	(25 ng/l)
Asbestos	0 (30,000 fibers/l)	(30,000 fibers/l)
Benzene*	0 (0.66 ug/l)	0 (0.67 ug/l)
Benzidine*	0 (0.12 ng/l)	0 (0.15 ng/l)
Beryllium*	0 (3.7 ng/l)	0 (3.9 ng/l)
Cadmium*	10 ug/l	10 ug/l
Carbon tetrachloride*	0 (0.4 ug/l)	0 (0.42 ug/l)
Chlordane*	0 (0.46 ng/l)	0 (22 ng/l)
Chlorinated benzenes		
Hexachlorobenzene*	0 (0.72 ng/l)	0 (21 ng/l)
1,2,4,5-Tetrachlorobenzene*	38 ug/l	180 ug/l
Pentachlorobenzene*	74 ug/l	570 ug/l
Trichlorobenzene*	Insufficient data	Insufficient data
Monochlorobenzene*	488 ug/l	488 ug/l
Chlorinated ethanes		
1,2-Dichloroethane*	0 (0.94 ug/l)	0 (0.94 ug/l)
1,1,1-Trichloroethane*	18.4 mg/l	19 mg/l
1,1,2-Trichloroethane*	0 (0.6 ug/l)	0 (0.6 ug/l)
1,1,2,2-Tetrachloroethane*	0 (0.17 ug/l)	0 (0.17 ug/l)
Hexachloroethane*	0 (1.9 ug/l)	0 (2.4 ug/l)
Monochloroethane	Insufficient data	Insufficient data
1,1-Dichloroethane*	Insufficient data	Insufficient data
1,1,1,2-Tetrachloroethane	Insufficient data	Insufficient data
Pentachloroethane	Insufficient data	Insufficient data
Chlorinated naphthalenes	Insufficient data	Insufficient data
Chlorinated phenols		
3-Monochlorophenol	0.1 ug/l (Organoleptic)	0.1 ug/l (Organoleptic)
4-Monochlorophenol	0.1 ug/l (Organoleptic)	0.1 ug/l (Organoleptic)
2,3-Dichlorophenol	0.04 ug/l (Organoleptic)	0.04 ug/l (Organoleptic)
2,5-Dichlorophenol	0.5 ug/l (Organoleptic)	0.5 ug/l (Organoleptic)
2,6-Dichlorophenol	0.2 ug/l (Organoleptic)	0.2 ug/l (Organoleptic)
3,4-Dichlorophenol	0.3 ug/l (Organoleptic)	0.3 ug/l (Organoleptic)
2,3,4,6-Tetrachlorophenol*	1.0 ug/l (Organoleptic)	1.0 ug/l (Organoleptic)
2,4,5-Trichlorophenol*	2600 ug/l	2600 ug/l

EXHIBIT C-10
(Continued)

EPA AMBIENT WATER QUALITY CRITERIA (WQC) FOR PROTECTION OF HUMAN HEALTH

CHEMICAL	CONCENTRATON a/	
	Aquatic Organisms and Drinking Water	Adjusted for Drinking Water Only b/
2,4,6-Trichlorophenol*	0 (1.2 ug/l)	0 (1.8 ug/l)
2-Methyl-4-chlorophenol	1800 ug/l (Organoleptic)	1800 ug/l (Organoleptic)
3-Methyl-4-chlorophenol	3000 ug/l (Organoleptic)	3000 ug/l (Organoleptic)
3-Methyl-6-chlorophenol	20 ug/l (Organoleptic)	20 ug/l (Organoleptic)
Chloroalkyl ethers		
bis-(Chloromethyl) ether*	0 (0.0038 ng/l)	0 (0.0039 ng/l)
bis-(2-Chloroethyl) ether*	0 (30 ng/l)	0 (30 ng/l)
bis-(2-Chloroisopropyl) ether	34.7 ug/l	34.7 ug/l
Chloroform*	0 (0.19 ug/l)	0 (0.19 ug/l)
2-Chlorophenol	0.1 ug/l (Organoleptic)	0.1 ug/l (Organoleptic)
Chromium Cr+6*	50 ug/l	50 ug/l
Cr+3*	170 mg/l	179 mg/l
Copper*	1 mg/l (Organoleptic)	1 mg/l (Organoleptic)
Cyanide*	200 ug/l	200 ug/l
DDT*	0 (0.024 ng/l)	0 (> 1.2 ng/l)
Dichlorobenzenes* (all isomers)	400 ug/l	470 ug/l
Dichlorobenzidines	0 (10.3 ng/l)	0 (20.7 ng/l)
Dichloroethylenes		
1,1-Dichloroethylene*	0 (33 ng/l)	0 (33 ng/l)
1,2-Dichloroethylene	Insufficient data	Insufficient data
Dichloromethane*	See Halomethanes	See Halomethanes
2,4-Dichlorophenol*	3.09 mg/l	3.09 mg/l
Dichloropropanes/Dichloropropenes		
Dichloropropanes	Insufficient data	Insufficient data
Dichloropropenes	87 ug/l	87 ug/l
Dieldrin*	0 (0.071 ng/l)	0 (1.1 ng/l)
2,4-Dimethylphenol	400 ug/l (Organoleptic)	400 ug/l (Organoleptic)
2,4-Dinitrotoluene*	0 (0.11 ug/l)	0 (0.11 ug/l)
1,2-Diphenylhydrazine*	0 (42 ng/l)	0 (46 ng/l)
Endosulfan*	74 ug/l	138 ug/l
Endrin	1 ug/l	1 ug/l
Ethylbenzene*	1.4 mg/l	2.4 mg/l
Fluoranthene	42 ug/l	188 ug/l
Haloethers	Insufficient data	Insufficient data
Halomethanes	0 (0.19 ug/l)	0 (0.19 ug/l)
Heptachlor*	0 (0.28 ng/l)	0 (11 ng/l)
Hexachlorobutadiene*	0 (0.45 ug/l)	0 (0.45 ug/l)
Hexachlorocyclohexanes (HCCH)		
alpha-HCCH*	0 (9.2 ng/l)	0 (13 ng/l)

EXHIBIT C-10
(Continued)

EPA AMBIENT WATER QUALITY CRITERIA (WQC) FOR PROTECTION OF HUMAN HEALTH

CHEMICAL	CONCENTRATON a/	
	Aquatic Organisms and Drinking Water	Adjusted for Drinking Water Only b/
beta-HCCH*	0 (16.3 ng/l)	0 (23.2 ng/l)
gamma-HCCH*	0 (12.3 ng/l)	0 (17.4 ng/l)
delta-HCCH	Insufficient data	Insufficient data
epsilon-HCCH	Insufficient data	Insufficient data
Technical-HCCH	0 (5.2 ng/l)	0 (7.4 ng/l)
Hexachlorocyclopentadiene*	206 ug/l	206 ug/l
Isophorone*	5.2 mg/l	5.2 mg/l
Lead*	50 ug/l	50 ug/l
Mercury*	144 ng/l	10 ug/l
Naphthalene	Insufficent data	Insufficient data
Nickel*	13.4 ug/l	15.4 ug/l
Nitrobenzene*	19.8 mg/l	19.8 mg/l
Nitrophenols		
2,4-Dinitro-o-cresol	13.4 ug/l	13.6 ug/l
Dinitrophenol*	70 ug/l	70 ug/l
Mononitrophenol	Insufficient data	Insufficient data
Trinitrophenol	Insufficient data	Insufficient data
Nitrosamines		
n-Nitrosodimethylamine*	0 (1.4 ng/l)	0 (1.4 ng/l)
n-Nitrosodiethylamine*	0 (0.8 ng/l)	0 (0.8 ng/l)
n-Nitrosodi-n-butylamine*	0 (6.4 ng/l)	0 (6.4 ng/l)
n-Nitrosodiphenylamine	0 (4.9 ug/l)	0 (7.0 ug/l)
n-Nitrosopyrrolidine*	0 (16 ng/l)	0 (16 ng/l)
Pentachlorophenol*	1.01 mg/l	1.01 mg/l
Phenol*	3.5 mg/l	3.5 mg/l
Phthalate esters		
Dimethylphthalate	313 mg/l	350 mg/l
Diethylphthalate*	350 mg/l	434 mg/l
Dibutylphthalate*	34 mg/l	44 mg/l
Di-2-ethylhexylphthalate*	15 mg/l	21 mg/l
Polychlorinated biphenyls (PCBs)*	0 (0.079 ng/l)	0 (> 12.6 ng/l)
Polynuclear aromatic hydrocarbons (PAHs)*	0 (2.8 ng/l)	0 (3.1 ng/l)
Selenium*	10 ug/l	10 ug/l
Silver*	50 ug/l	50 ug/l
2,3,7,8-TCDD*	0 (0.000013 ng/l)	0 (0.00018 ng/l)
Tetrachloroethylene*	0 (0.8 ug/l)	0 (0.88 ug/l)
Thallium*	13 ug/l	17.8 ug/l

EXHIBIT C-10
(Continued)

EPA AMBIENT WATER QUALITY CRITERIA (WQC) FOR PROTECTION OF HUMAN HEALTH

CHEMICAL	CONCENTRATON a/	
	Aquatic Organisms and Drinking Water	Adjusted for Drinking Water Only b/
Toluene*	14.3 mg/l	15 mg/l
Toxaphene*	0 (0.71 ng/l)	0 (26 ng/l)
Trichloroethylene*	0 (2.7 ug/l)	0 (2.8 ug/l)
Vinyl chloride*	0 (2.0 ug/l)	0 (2.0 ug/l)
Zinc*	5 mg/l (Organoleptic)	5 mg/l (Organoleptic)

* Toxicity values necessary for risk characterization are given in Appendix C.

a/ The criterion value is zero for all potential carcinogens. The concentration value given in parentheses for potential carcinogens corresponds to a risk of 10^{-6}, which is the midpoint of the range of 10^{-5} to 10^{-7} given in water quality criteria documents. To obtain concentrations corresponding to risks of 10^{-5}, the 10^{-6} concentrations should be multiplied by 10. To obtain concentrations corresponding to risks of 10^{-7}, the 10^{-6} concentrations should be divided by 10.

b/ These adjusted criteria, for drinking water ingestion only, were derived from published EPA ambient water quality criteria (45 Federal Register 79318-79379, November 28, 1980) for combined fish and drinking water ingestion and for fish ingestion alone. The adjusted values are not official EPA ambient water quality criteria, but may be appropriate for sites with potentially contaminated ground water. In the derivation of these values, intake was assumed to be 2 liters/day for drinking water and 6.5 grams/day for fish, and human body weight was assumed to be 70 kilograms. Values for bioconcentration factor, carcinogenic potency, and acceptable daily intake were those used for water quality criteria development.

c/ Criteria designated as organoleptic are based on taste and odor effects, not human health effects. Health-based water quality criteria are not available for these chemicals.

EXHIBIT C-11

EPA DRINKING WATER HEALTH ADVISORIES AND RECOMMENDED CONCENTRATION

CHEMICAL	Health Advisories					Reference Concentration for Potential Carcinogens b/ (ug/l) 70 kg
	One-day (ug/l) 10 kg	Ten-day (ug/l) 10 kg	Longer-term a/ (ug/l) 10 kg	Longer-term a/ (ug/l) 70kg	Lifetime (ug/l) 70 kg	
Acrylamide	1500	300	20	70	--	0.01
Alachlor	15000	15000	NA	NA	NA	0.15
Aldicarb*	12	12	12	42	42	NA
Arsenic*	50	50	50	50	50	0.0022
Barium*	--	--	--	--	1800	NA
Benzene*	233	233	NA	NA	NA	0.35
Cadmium*	43	8	5	18	18	NA
Carbofuran	50	50	50	180	180	NA
Carbon Tetrachloride*	4000	160	71	250	--	0.3
Chlordane*	63	63	--	--	--	0.0218
Chlorobenzene*	1800	1800	9000	30000	3150	NA
Chromium*	1400	1400	240	840	170	NA
Cyanide*	220	220	220	750	750	NA
2,4-D	1100	300	--	--	350	NA
Dibromochloropropane	200	50	NA	NA	NA	0.025
o-/m-Dichlorobenzene*	8930	8930	8930	31250	3125	NA
p-Dichlorobenzene	10700	10700	10700	37500	3750	NA
1,2-Dichloroethane*	740	740	740	2600	NA	0.95
1,1-Dichloroethylene*	1000	1000	1000	3500	--	0.24
cis-1,2-Dichloroethylene	4000	1000	1000	3500	350	NA
trans-1,2-Dichloroethylene	2720	1000	1000	3500	350	NA

C-53

EXHIBIT C-11
(Continued)

EPA DRINKING WATER HEALTH ADVISORIES AND RECOMMENDED CONCENTRATION

CHEMICAL	Health Advisories					Reference Concentration for Potential Carcinogens b/
	One-day (ug/l) 10 kg	Ten-day (ug/l) 10 kg	Longer-term a/ (ug/l) 10 kg	Longer-term a/ (ug/l) 70kg	Lifetime (ug/l) 70 kg	(ug/l) 70 kg
Dichloromethane*	13300	1500	--	--	--	5
1,2-Dichloropropane	--	90	--	--	--	0.56
p-Dioxane	5680	568	--	--	--	--
Dioxin*	0.001	0.0001	0.00001	0.000035	--	2.2 x 10-7
Endrin	20	5	4.5	16	1.6	NA
Epichlorohydrin*	140	140	76	76	--	3.54
Ethylbenzene*	21000	2100	--	--	3400	NA
Ethylene Dibromide*	8	8	NA	NA	NA	0.0005
Ethylene Glycol*	19000	5500	5500	19250	--	NA
Heptachlor*	10	10	--	--	--	0.0104
Heptachlor Epoxide*	--	--	--	--	--	0.0006
Hexachlorobenzene*	50	50	50	175	--	0.02
n-Hexane	13000	4000	4000	14000	--	NA
Lead*	--	--	20 ug/day	20 ug/day	20 ug/day	0.031
Lindane*	1200	1200	33	120	--	0.02655
Mercury*	--	--	--	--	5.5	NA
Methoxychlor	6400	2000	--	--	1700	NA
Methyl Ethyl Ketone*	75000	7500	2500	8600	860	NA
Nickel*	--	1000	--	--	350	NA
Nitrate c/	10000 (4 kg) 111000 (10 kg)	10000 (4 kg) 111000 (10 kg)	--	--	10000	NA
Nitrite c/	1000 (4 kg) 11000 (10 kg)	1000 (4 kg) 11000 (10 kg)	--	--	1000	NA

EXHIBIT C-11
(Continued)

EPA DRINKING WATER HEALTH ADVISORIES AND RECOMMENDED CONCENTRATION

CHEMICAL	Health Advisories					Reference Concentration for Potential Carcinogens b/
	One-day (ug/l)	Ten-day (ug/l)	Longer-term a/ (ug/l)		Lifetime (ug/l)	(ug/l)
	10 kg	10 kg	10 kg	70kg	70 kg	70 kg
Oxamyl	350	350	--	--	810	NA
PCBs*	--	--	--	--	--	--
Pentachlorophenol*	1000	300	300	1050	1050	NA
Styrene*	27000	20000	20000	70000	--	0.014
Tetrachloroethylene*	--	34000	1940	6800	--	0.7
Toluene*	18000	6000	--	--	10800	NA
Toxaphene*	500	80	--	--	--	0.031
2,4,5-TP*	200	200	--	--	260	NA
1,1,1-Trichloroethane*	140000	35000	35000	125000	1000	22000
Trichloroethylene*	--	--	--	--	--	2.8
Vinyl Chloride*	2600	2600	13	46	NA	0.015
Xylenes*	12000	7800	7800	27300	2200	NA

* Toxicity values necessary for risk characterization are given in Appendix C.

a/ Longer term health advisories are for exposures ranging from several months to several years and should generally be compared only to estimated short-term concentrations (STC).

b/ The concentration given corresponds to a potential carcinogenic risk of 1E-06. To obtain concentrations corresponding to risks of 1E-04 and 1E-05, the 1E-06 concentrations should be multiplied by 100 and 10, respectively. To obtain concentrations corresponding to risks of 1E-07, the 1E-06 concentrations should be divided by 10.

c/ The one- and ten-day health advisories for nitrate and nitrite are given for both a 4 kg newborn and a 10 kg infant.

EXHIBIT C-12

CLEAN AIR ACT NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS)

CHEMICAL	CONCENTRATION ug/m3
Carbon monoxide	40,000 (1-hour) a/
	10,000 (8-hour) a/
Hydrocarbons (non-methane)	160 (3-hour) a/
Lead	1.5 (90-day) b/
Nitrogen dioxide	100 (1-year) c/
Ozone	235 (1-hour) a/
Particulate Matter	260 (24-hour) a/
	75 (1-year) d/
Sulfur oxides	365 (24-hour) a/
	80 (1-year) c/

a/ Maximum concentration not to be exceeded more than once per year.

b/ Three-month arithmetic mean concentration.

c/ Annual arithmetic mean concentration.

d/ Annual geometric mean concentration.

APPENDIX D

DETAILED PROCEDURES FOR DETERMINING TOXICITY CONSTANTS FOR INDICATOR CHEMICAL SELECTION

The method for selecting indicator chemicals for a site, described in Chapter 2 of this manual, requires the determination of toxicity constants (T). For many chemicals, these values are given in Appendix C. This appendix (Appendix D) presents methods for calculating toxicity constants for chemicals not listed in Appendix C.[1] If, in the process of preparing a public health evaluation for a site, such chemicals are found, you should request help from EPA headquarters before doing these calculations. As new information becomes available or new chemicals are identified as problems, the list in Appendix C will be updated and expanded.

Toxicity constants, T, are medium-specific. A toxicity constant for use with drinking water concentrations is referred to as ${}^{w}T$, whereas one for concentrations in air is ${}^{a}T$, and and one for concentrations in soil is ${}^{s}T$. Toxicity constants for potential carcinogens are based on the ED_{10}[2]; for noncarcinogens they are based on the minimum effective dose (MED) and a severity of effects rating. All toxicity constants also have standard intake assumptions built in. Units of toxicity constants are the inverse of concentration units.

Values of ${}^{a}T$, ${}^{s}T$, and ${}^{w}T$ for a variety of compounds are given in Appendix C. In the event that values are not present in Appendix C, they can be calculated as follows:

Potential Carcinogens

$$ {}^{w}Tc = \frac{2 \text{ liters drinking water/day}}{70 \text{ kg} \bullet ED_{10}} \qquad [1] $$

$$ {}^{s}Tc = \frac{0.0001 \text{ kg soil/day}}{70 \text{ kg} \bullet ED_{10}} \qquad [2] $$

$$ {}^{a}Tc = \frac{20 \text{ m}^3 \text{ air/day}}{70 \text{ kg} \bullet ED_{10}} \qquad [3] $$

---

[1] Appendix D is a copy of Appendix D in: EPA, Superfund Public Health Evaluation Manual, Office of Emergency and Remedial Response, October 1986.

[2] ED_{10} = dose in mg/kg/day at which 10% incidence above control is observed for a tumor type showing a statistically significant incidence.

where the ED_{10} is derived from carcinogenicity dose-response data and is expressed in mg/kg/day.

Noncarcinogens

$$^{w}Tn = \frac{2 \text{ liters drinking water/day} \cdot RVe}{MED \text{ (oral)}} \quad [4]$$

$$^{s}Tn = \frac{0.0001 \text{ kg soil/day} \cdot RVe}{MED \text{ (oral)}} \quad [5]$$

$$^{a}Tn = \frac{20 \text{ m}^3 \text{ air/day} \cdot RVe}{MED \text{ (inhalation)}} \quad [6]$$

where RVe is a rating value based on the severity of effect and scored as indicated in Exhibit D-1, and MED is the human minimum effective dose in mg/day for a given effect. If the MED is given in mg/kg/day, multiply it by 70 and then substitute it into the above equation.

The soil toxicity constant (^{s}T) is incorporated as a way to estimate the overall exposure that might be contributed by contaminated soil. Inclusion of ^{s}T in the indicator selection process is a way to use the soil concentration data gathered in most site characterizations, in part so that compounds found in soil and not in air and water could be considered in indicator compound scoring. The ^{s}T equation is based on a child's consumption of contaminated soil as detailed in a recent ORD risk assessment of contaminated soil (EPA, 1984).

The ORD document estimates that children between the ages of two and six consume at least 100 mg of soil per day, and that in situations of direct ingestion of soil (i.e., pica) the rate could go as high as 5 g per day. The lower value was selected for this procedure because it was more comparable to the standard consumption values used in calculating the other T values. The 5 g per day value is representative of a pathologic state (pica), and using it to calculate ^{s}T would correspond to assuming 8 liters or more as the daily consumption of water (to reflect the diabetic who consumes 8 liters of water per day).

Although Equations 2 and 5 are based on ingestion by a child, the intake is not normalized to an equivalent lifetime intake. The equations use an intake rate during childhood rather than an lifetime average daily intake to ensure that compounds are identified on the basis of their potential to harm a child. Thus, the equations compare a child's daily intake rate to a lifetime average daily intake (expressed as an MED or an ED_{10}), which, strictly speaking, may be inappropriate. Unfortunately, the most appropriate data to use, dose-response information for children, do not exist, and even data for dose-response relationships in immature animals are rare. What little

EXHIBIT D-1

RATING CONSTANTS (RVe) FOR NONCARCINOGENS a/

Effect	Severity Rating (RVe)
Enzyme induction or other biochemical change with no pathologic changes and no change in organ weights.	1
Enzyme induction and subcellular proliferation or other changes in organelles but no other apparent effects.	2
Hyperplasia, hypertrophy or atrophy, but no change in organ weights.	3
Hyperplasia, hypertrophy or atrophy with changes in organ weights.	4
Reversible cellular changes: cloudy swelling, hydropic change, or fatty changes.	5
Necrosis, or metaplasia with no apparent decrement of organ function. Any neuropathy without apparent behavioral, sensory, or physiologic changes.	6
Necrosis, atrophy, hypertrophy, or metaplasia with a detectable decrement of organ functions. Any neuropathy with a measurable change in behavioral, sensory, or physiologic activity.	7
Necrosis, atrophy, hypertrophy, or metaplasia with definitive organ dysfunction. Any neuropathy with gross changes in behavior, sensory, or motor performance. Any decrease in reproductive capacity, any evidence of fetotoxicity.	8
Pronounced pathologic changes with severe organ dysfunction. Any neuropathy with loss of behavioral or motor control or loss of sensory ability. Reproductive dysfunction. Any teratogenic effect with maternal toxicity.	9
Death or pronounced life-shortening. Any teratogenic effect without signs of maternal toxicity.	10

a/ Rating scale identical to that used by EPA in the RQ adjustment process, as described in EPA (1983).

information is available seems to indicate that the young are generally more sensitive to the toxic effects of chemicals than adults. Although this approach is not strictly accurate it errs on the more protective side, while at the same time achieving the goal of being a simple way to incorporate soil concentration information into the indicator selection process.

Although not used directly in the calculation of indicator scores for potential carcinogens, a qualitative weight-of-evidence rating is considered in the final selection of indicators. The EPA weight-of-evidence criteria (EPA, 1986) are given in Exhibit D-2 and should be used to categorize potential carcinogens not listed in Appendix C. The EPA approach for determining weight of evidence is similar to the International Agency for Research on Cancer (IARC) approach, differing primarily by having an additional category for "no evidence of carcinogenicity in humans" and revised criteria for defining evidence as "sufficient", "limited", or "inadequate."

REFERENCES FOR APPENDIX D

U.S. EPA, 1983. Methodology and Guidelines for Reportable Quantity Determinations Based on Chronic Toxicity Data, External Review Draft. Prepared by the Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment. ECAO-CIN-R245.

U.S. EPA, 1986. Guidelines for Carcinogen Risk Assessment. Federal Register 51:33992.

U.S. EPA, 1984. Risk Analysis of TCDD Contaminated Soil. Prepared by the Exposure Assessment Group, Office of Health and Environmental Assessment. EPA 600/8-84-031.

EXHIBIT D-2

EPA WEIGHT-OF-EVIDENCE CATEGORIES FOR POTENTIAL CARCINOGENS

EPA Category	Description of Group	Description of Evidence
Group A	Human Carcinogen	Sufficient evidence from epidemiologic studies to support a causal association between exposure and cancer
Group B1	Probable Human Carcinogen	Limited evidence of carcinogenicity in humans from epidemiologic studies
Group B2	Probable Human Carcinogen	Sufficient evidence of carcinogenicity in animals, inadequate evidence of carcinogenicity in humans
Group C	Possible Human Carcinogen	Limited evidence of carcinogenicity in animals
Group D	Not Classified	Inadequate evidence of carcinogenicity in animals
Group E	No Evidence of Carcinogenicity in Humans	No evidence for carcinogenicity in at least two adequate animal tests or in both epidemiologic and animal studies

APPENDIX E

BLANK WORKSHEETS

WORKSHEET 1-1
TIMETABLE FOR DEMONSTRATION OF RISK-BASED VARIANCE FROM SECONDARY CONTAINMENT

INSTRUCTIONS:

1. Fill in Starting Date and Finishing Date.
2. Place a ✓ at expected time of completion for each activity.
3. Next to ✓, place expected date in parenthesis (e.g., (10/25/88))

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Starting Date ☐

Finishing Date ☐

WEEK

ACTIVITY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
I. Source Characterization																										
a. Identify Physical and Chemical Characteristics of Constituents																										
b. Select Indicator Chemicals																										
c. Determine Worst Case Release Volumes																										
II. Hydrogeological Characteristics																										
a. Characterize Climate																										
b. Characterize Regional and Site Geology																										
c. Characterize Unsaturated and Saturated Zones																										
d. Characterize Surface Water																										
III. Surrounding Land Use, Water Use, and Water Quality Characteristics																										
a. Characterize Ground-Water Use and Quality																										
b. Characterize Surface Water Use and Quality																										
c. Characterize Surrounding Land Use and Quality																										

WORKSHEET 1-1
TIMETABLE FOR DEMONSTRATION OF RISK-BASED VARIANCE FROM SECONDARY CONTAINMENT
(Continued)

Starting Date ☐

Finishing Date ☐

WEEK

ACTIVITY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
IV. Exposure Point Concentration																										
a. Identify Exposure Pathways																										
b. Estimate Exposure Point Concentrations																										
V. Health Effects Evaluation																										
a. Compare Exposure Point Concentrations to Established Health Standards																										
b. Estimate Chemical Intakes																										
c. Determine Chemical Toxicities																										
d. Characterize Risk																										
VI. Environmental Impact Evaluation																										
a. Compare Exposure Point Concentrations to Quality Standards																										
b. Derive Site Specific Criteria																										
c. Evaluate Site Specific Exposure Points																										
VII. Preparation of the "No-Substantial Hazard" Demonstration																										
a. Summarize Results of the Risk-Based Assessment																										
b. Prepare Supporting Documentation																										
c. Submit to Regional Administrator																										

Page _____ of _____

WORKSHEET 2-1

PHYSICAL AND CHEMICAL CHARACTERISTICS OF CONSTITUENTS

INSTRUCTIONS:

1. List all chemicals and their Chemical Abstract Service (CAS) number.
2. Refer to Exhibit C-1 and C-2 and record each chemical's solubility, vapor pressure, Henry's law constant, Koc, log Kow, and half-lives in ground water (GW), surface water (SW), soil, and air. Refer to chemical handbooks and record each chemical's specific gravity, viscosity and oxidation state.

Facility ID: __________

Date: __________

Analyst: __________

Quality Control: __________

Chemical	CAS #	Water Solubility (mg/l)	Oxidation State	Specific Gravity	Viscosity a/ (centipoise)	Vapor Pressure (mm Hg)	Henry's Law Constant (atm-m3/mol)	Koc	log Kow	Half-Life (Days)			
										GW	SW	Soil	Air

a/ At 20° C.

ASSUMPTIONS:

List all major assumptions made in the development of data for this worksheet:

Page ____ of ____

WORKSHEET 2-2

INDICATOR CHEMICAL TOXICITY INFORMATION

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

INSTRUCTIONS:

1. Record compounds from Worksheet 2-1, then refer to Exhibit C-3 and C-5 and note whether they are classified as potential carcinogen (PC) or noncarcinogen (NC) or both.
2. Record the rating value (noncarcinogens, Exhibit C-5) or EPA category (potential carcinogens, Exhibit C-4) for each compound in each class. If there are route-specific differences (i.e., oral or inhalation), record both values.
3. Refer to Exhibits C-3 and C-5 and record the toxicity constant value associated with water.

Chemical	Toxicologic Class (PC, NC)	Rating Value/EPA Category a/	Water Toxicity Constant (l/mg)

---

a/ Rating value is for severity-of-effect for noncarcinogens, range is 1(low) to 10(high); EPA category is a qualitative weight-of-evidence designation for potential carcinogens; explanation of the categories is presented in Exhibit 2-2. Information taken from Appendix C.

ASSUMPTIONS:

List all the major assumptions made in developing the data for this worksheet:

Page ____ of ____

WORKSHEET 2-3

CALCULATION OF OVERALL CHEMICAL CONCENTRATIONS IN TANK SYSTEMS

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

INSTRUCTIONS:

1. Identify the chemicals in the tank systems (use one worksheet for each chemical).
2. Identify tank systems that contain each chemical.
3. Identify annual throughput of each tank system in liters (to convert from gallons to liters multiply by 3.7854).
4. Identify chemical concentrations (minimum, maximum, representative) in each tank system.
5. For each tank system, calculate the annual mass of chemical handled by the tank (the annual mass equals the product of the annual throughput and concentration, divided by 1,000,000 to convert to kilograms).
6. Calculate total annual throughput of all tanks and total annual mass of chemical handled in all tank systems.
7. Calculate the overall chemical concentration within the tank systems (divide total annual mass of chemical by total annual throughput and multiply by 1,000,000 to convert to milligrams).

Chemical: ____________

		Chemical Concentration In Tank System (mg/l)			Annual Mass of Chemical Handled in Tank System (kg)		
Tank System ID	Annual Throughput (liters)	Minimum	Maximum	Representative	Minimum	Maximum	Representative
Total:							
Overall chemical concentration in tank systems:							

ASSUMPTIONS:

List all major assumptions made in developing the data for this worksheet:

Page ____ of ____

WORKSHEET 2-4

SCORING FOR INDICATOR CHEMICAL SELECTION: OVERALL CONCENTRATIONS, Koc, AND log Kow VALUES

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

INSTRUCTIONS:

1. Write down each chemical found within the tank system and its Koc and log Kow values (from Worksheet 2-1) (use additional worksheets if necessary).
2. If more than 20 chemicals are listed, identify those with the ten highest Koc values with an H and those with the ten lowest Koc values with an L. In addition, identify those with the ten highest log Kow values with an H* and those with the ten lowest log Kow values with an L*.
3. Record an overall minimum, maximum and "representative" concentration from Worksheet 2-3 and enter it; indicate in footnotes the basis of the representative value (e.g., Waste Analysis Report).
4. Record indicator chemical toxicity constant value from Worksheet 2-2.
5. Record the freshwater chronic water quality criteria from Exhibit 7-2. If not available state NA.

Chemical	Koc Value	log Kow Value	Overall Chemical Concentration (mg/l)				Indicator Chemical Toxicity Constant (l/mg)		Fresh Chronic Criteria (mg/l)
			Minimum	Maximum	Representative a/	Reference b/	NC	PC	

a/ Mean of reported values used as representative concentration for all tank systems used to store or treat the chemical; zero used for all values reported as below detection limit.

b/ Page numbers follow document designation.

ASSUMPTIONS:

List all the major assumptions made in developing the data for this worksheet; also indicate any concerns about the waste analysis data.

Page ____ of ____

E-8

WORKSHEET 2-5

SCORING FOR INDICATOR CHEMICAL SELECTION: CALCULATION OF INDICATOR SCORE VALUES AND TENTATIVE RANK FOR CARCINOGENIC EFFECTS

INSTRUCTIONS:

1. List all of the chemicals to be considered as potential carcinogens.
2. Calculate overall concentration times toxicity (CT) values using the information from Worksheets 2-1 and 2-2. Calculate a CT based on the overall minimum, maximum, and representative concentrations.
3. Rank the compounds based on their minimum, maximum, and representative indicator score values. Also, enter their EPA weight-of-evidence category in the final column.

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Chemical	Indicator Score Value			Tentative Rank			Weight of Evidence
	Minimum	Maximum	Representative	Maximum	Minimum	Representative	

ASSUMPTIONS:

List all major assumptions made in developing the data for this worksheet:

WORKSHEET 2-6

Page ____ of ____

SCORING FOR INDICATOR CHEMICAL SELECTION:
CALCULATION OF INDICATOR SCORE VALUES AND TENTATIVE RANK FOR NONCARCINOGENIC EFFECTS

INSTRUCTIONS:

1. List all of the chemicals to be considered for noncarcinogenic effects.
2. Calculate overall concentration times toxicity (CT) values using the information from Worksheets 2-1 and 2-2. Calculate CT values based on the overall minimum, maximum, and representative concentrations.
3. Rank the compounds based on their minimum, maximum, and representative indicator score values. Also enter the severity-of-effects rating value(s) in the final column.

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Chemical	Indicator Score Value			Tentative Rank			Rating Value(s)	
	Minimum	Maximum	Representative	Minimum	Maximum	Representative	Oral	Inhalation

ASSUMPTIONS:

List all major assumptions made in developing the data for this worksheet:

Page ___ of ___

WORKSHEET 2-7

SCORING FOR INDICATOR CHEMICAL SELECTION:
CALCULATION OF INDICATOR SCORE VALUES AND TENTATIVE RANK FOR ENVIRONMENTAL EFFECTS

Facility ID: ______
Date: ______
Analyst: ______
Quality Control: ______

INSTRUCTIONS:

1. List all of the chemicals to be considered for environmental effects.
2. Calculate indicator scores by dividing overall concentration by fresh water chronic water quality criteria using the information from Worksheets 2-1 and 2-2. Calculate water quality indicator score values based on the overall minimum, maximum, and representative concentrations.
3. Rank the compounds based on their minimum, maximum, and representative indicator score values.

	Indicator Score Value			Tentative Rank		
Chemical	Minimum	Maximum	Representative	Minimum	Maximum	Representative

ASSUMPTIONS:

List all major assumptions made in developing the data for this worksheet:

Page ____ of ____

WORKSHEET 2-8

SCORING FOR INDICATOR CHEMICAL SELECTION FOR HUMAN HEALTH EFFECTS EVALUATION: EVALUATION OF EXPOSURE FACTORS AND FINAL CHEMICAL SELECTION

INSTRUCTIONS:

Facility ID: ____________
Date: ____________
Analyst: ____________
Quality Control: ____________

1. List the top 15 to 20 PC and NC chemicals based on health-based indicator score (ISH) values, giving their ISH values and their ranking (use additional sheets).
2. Refer to Worksheet 2-1 and record each chemical's solubility, vapor pressure, Henry's law constant, Koc, and half-lives in ground water, surface water, soil, and air.
3. Select the final 10 to 15 indicator chemicals based on the guidelines presented in Section 2.3.3. Use your judgment -- if a compound has a high water solubility and a long half-life, yet is ranked lower than a compound with minimal water solubility and a short half-life, you may wish to move it up in the ranking.
4. Document any changes in ranking made because of exposure factors.
5. In the last column indicate with a "+" those chemicals that have been selected as indicator chemicals (IC).

Chemical	ISH Values a/		Ranking		Water Solubility (mg/l)	Vapor Pressure (mm Hg)	Henry's Law Constant (atm-m3/mole)	Koc	Half-Life (Days)				IC
	PC	NC	PC	NC					GW	SW	Soil	Air	

a/ Based on overall representative concentrations.

ASSUMPTIONS:

List all major assumptions made in the development of data for this worksheet:

Page ____ of ____

WORKSHEET 2-9

SCORING FOR INDICATOR CHEMICAL SELECTION FOR ENVIRONMENTAL IMPACT EVALUATION: EVALUATION OF EXPOSURE FACTORS AND FINAL CHEMICAL SELECTION

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

INSTRUCTIONS:

1. List the top 15 to 20 chemicals according to environmental quality-based indicator score (ISE) values, giving their ISE values and their ranking. Also list chemicals that could not be scored (use additional sheets).
2. Refer to Worksheet 2-1 and record each chemical's solubility, vapor pressure, Henry's law constant, Koc, and half-lives in ground water (GW), surface water (SW), soil, and air.
3. Select the final 10 to 15 indicator chemicals based on the guidelines presented in Section 2.2.3. Use your judgment -- if a compound has a high water solubility and a long half-life, yet is ranked lower than a compound with minimal water solubility and a short half-life, you may wish to move it up in the ranking.
4. Document any changes in ranking made because of exposure factors.
5. In the last column indicate with a "+" those chemicals that have been selected as indicator chemicals (IC).

Chemical	ISE Values a/	Ranking	Water Solubility (mg/l)	Vapor Pressure (mm Hg)	Henry's Law Constant (atm-m3/mole)	Koc	Half-Life (Days) GW	SW	Soil	Air	IC

a/ Based on overall representative concentrations.

ASSUMPTIONS:

List all major assumptions made in the development of data for this worksheet:

Page ____ of ____

WORKSHEET 2-10

RELEASE VOLUME PROFILES ASSOCIATED WITH EACH TANK SYSTEM

Facility ID: ____________

Cluster: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

INSTRUCTIONS:

1. List each tank system, its components for which a variance is being sought or for which a variance was previously granted, the locations of the components (i.e., aboveground, onground, inground, underground), the tank volume, annual throughput (not necessary for aboveground components), and maximum daily throughput (only necessary for aboveground ancillary equipment).
2. Fill in the annual release volumes for the components according to the rules specified in the text.
3. For each tank system, sum the release volumes of the components and record the result. Note, however, that release volumes for underground, inground, and onground components in the same tank system should not be added. Only the release volumes from one of these components should be counted in the total to avoid double counting.

Tank System	Tank System Component	Component Location	Tank Volume (gallons)	Annual Throughput (gallons)	Maximum Daily Throughput (gallons)	Annual Release Volume (gallons)	
						Year 1	Years 2-20 (per year)
________	________	________	________	________	________	________	________
	________	________	________	________	________	________	________
	________	________	________	________	________	________	________
					Total	________	________
________	________	________	________	________	________	________	________
	________	________	________	________	________	________	________
	________	________	________	________	________	________	________
					Total	________	________
________	________	________	________	________	________	________	________
	________	________	________	________	________	________	________
	________	________	________	________	________	________	________
					Total	________	________
________	________	________	________	________	________	________	________
	________	________	________	________	________	________	________
	________	________	________	________	________	________	________
					Total	________	________

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WORKSHEET 2-11

RELEASE MASS PROFILES ASSOCIATED WITH EACH INDICATOR CHEMICAL: MINIMUM CONCENTRATION

INSTRUCTIONS:

1. Fill out a separate worksheet for each indicator chemical.
2. Identify the tank system(s) that contain the indicator chemical.
3. List the minimum concentration within the tank systems from Worksheet 2-3.
4. List the corresponding annual release volumes from Worksheet 2-8 for each tank system.
5. Calculate for the indicator chemical the mass released (in kilograms) for each tank system (annual mass released equals the annual release volume (in gallons) multiplied by 3.7854 to convert to liters, multiplied by the minimum concentration (in mg/liter), multiplied by 10^{-6} to convert to kilograms).
6. Calculate the total chemical mass released by summing the masses for the individual tank systems.

Facility ID: ___

Cluster: ___

Date: ___

Analyst: ___

Quality Control: ___

Indicator Chemical: ___

Tank System	Minimum Concentration (mg/liter)	Annual Volume Released		Annual Mass Released (kg)	
		Year 1	Years 2-20 (per year)	Year 1	Years 2-20 (per year)
			TOTAL		

Page ____ of ____

WORKSHEET 2-12

RELEASE MASS PROFILES ASSOCIATED WITH EACH INDICATOR CHEMICAL: MAXIMUM CONCENTRATION

INSTRUCTIONS:

1. Fill out a separate worksheet for each indicator chemical.
2. Identify the tank system(s) that contain the indicator chemical.
3. List the maximum concentration within the tank systems from Worksheet 2-3.
4. List the corresponding annual release volumes from Worksheet 2-8 for each tank system.
5. Calculate for the indicator chemical the mass released (in kilograms) for each tank system (annual mass released equals the annual release volume (in gallons) multiplied by 3.7854 to convert to liters, multiplied by the maximum concentration (in mg/liter), multiplied by 10^{-6} to convert to kilograms).
6. Calculate the total chemical mass released by summing the masses for the individual tank systems.

Facility ID: ____________

Cluster: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Indicator Chemical: ____________

Tank System	Maximum Concentration (mg/liter)	Annual Volume Released (gallons)		Annual Mass Released (kg)	
		Year 1	Years 2-20 (per year)	Year 1	Years 2-20 (per year)
			TOTAL		

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WORKSHEET 2-13

RELEASE MASS PROFILES ASSOCIATED WITH EACH INDICATOR CHEMICAL: REPRESENTATIVE CONCENTRATION

INSTRUCTIONS:

1. Fill out a separate worksheet for each indicator chemical.
2. Identify the tank system(s) that contain the indicator chemical.
3. List the representative concentration within the tank systems from Worksheet 2-3.
4. List the corresponding annual release volumes from Worksheet 2-8 for each tank system.
5. Calculate for the indicator chemical the mass released (in kilograms) for each tank system (annual mass released equals the annual release volume (in gallons) multiplied by 3.7854 to convert to liters, multiplied by the representative concentration (in mg/liter), multiplied by 10^{-6} to convert to kilograms).
6. Calculate the total chemical mass released by summing the masses for the individual tank systems.

Facility ID: ______
Cluster: ______
Date: ______
Analyst: ______
Quality Control: ______

Indicator Chemical: ______

Tank System	Representative Concentration (mg/liter)	Annual Volume Released (gallons)		Annual Mass Released (kg)	
		Year 1	Years 2-20 (per year)	Year 1	Years 2-20 (per year)
			TOTAL		

Page _____ of _____

WORKSHEET 4-1

PROXIMITY AND WITHDRAWAL RATES OF GROUND-WATER USERS

INSTRUCTIONS:

1. Indicate the location of ground-water wells in the area.
2. List the approximate distance of the well in meters from the release source (i.e., tank system).
3. Indicate the depth of the well in meters.
4. Indicate the type of user associated with each well (e.g., domestic, residential, agricultural).
5. Specify peak, annual, and seasonal (if applicable) withdrawal rates.
6. Add any additional comments, such as the nature of seasonal use.

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Well ID #	Location	Distance from Release Source (m)	Well Depth (m)	Type of User	Withdrawal Rates (g/day)			Comments
					Peak	Annual	Seasonal	

Page ____ of ____

WORKSHEET 4-2

MEASURED GROUND-WATER CONCENTRATIONS OF BACKGROUND CHEMICALS

INSTRUCTIONS:

1. List all selected background chemicals and indicator chemicals.
2. For each chemical listed, identify the release source.
3. List the range of measured upgradient ambient concentrations and median concentration for each chemical.
4. List the range of measured downgradient ambient concentrations and median concentration for each chemical.
5. List the general or specific (if applicable) location of the sampling (point(s) used to determine the maximum measured concentration.

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

		Upgradient Ambient Concentrations			Downgradient Ambient Concentrations				
Chemical	Suspended Release Source	Range a/	Median	# of Samples	Range a/	Median	# of Samples	Location of Maximum Measurements	Comments

a/ If available, in some cases only a single data point may be available.

Page _____ of _____

WORKSHEET 4-3

COMPARISON OF BACKGROUND CHEMICAL CONCENTRATIONS IN GROUND WATER TO DRINKING WATER STANDARDS AND GUIDELINES

INSTRUCTIONS:

1. List all background and indicator chemicals.
2. For each chemical, list the median and maximum ambient concentrations.
3. List any relevant EPA standards and the source of the standard (i.e., MCL, MCLG, WQC).a/
4. Under the comments section, indicate whether the background concentrations exceed or fall below the standards or whether no standards are available.

Facility ID: ______________

Date: ______________

Analyst: ______________

Quality Control: ______________

Chemical	Median Concentration	Maximum Concentration	Relevant EPA Standard	Source of the Standard	Comments

---

a/ MCL = maximum contaminant level
MCLG = maximum contaminant level goal
WQC = water quality criteria

Page _____ of _____

WORKSHEET 4-4

TREATMENT OPTIONS FOR REDUCING CONTAMINANT LEVELS

INSTRUCTIONS:

1. List use under consideration.
2. List all contaminants at levels exceeding those permissible to support the use.
3. For each contaminant, identify the necessary contamination reduction and potential methods to achieve the reduction.

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Potential Future Use: ____________

Contaminant	Concentration		Treatment Options	Level of Contaminant Treatment		
	Current Maximum	Necessary for Potential Use		Reduction	Duration	Treatment Costs

Page ____ of ____

WORKSHEET 4-5

SURFACE WATER CONTAMINATION SOURCES

INSTRUCTIONS:

1. List all potential contamination sources.
2. For each source list the water body into which it discharges.
3. If applicable and available, list discharge rate, contaminant load allocations, and NPDES permit number.

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Source	Water Body	Discharge Rate (m3/day)	Contaminant Load Allocations	NPDES #	Comments

Page _____ of _____

WORKSHEET 4-6

MEASURED SURFACE WATER CONCENTRATIONS OF BACKGROUND CHEMICALS

INSTRUCTIONS:

1. List all surface water bodies in the area that could potentially be contaminated by a release.
2. For each water body list all selected background chemicals.
3. For each chemical listed, identify the release source.
4. List the range and median measured ambient concentrations for each water body.
5. Identify the sampling location(s) used to determine the maximum concentration.

Facility ID: __________

Date: __________

Analyst: __________

Quality Control: __________

Water Body	Chemical	Suspected Release Source	Ambient Concentrations		Number of Samples	Location of Maximum Measurement	Comment
			Range	Median			

Page _____ of _____

WORKSHEET 4-7

SUMMARY OF CURRENT AND FUTURE USES OF SURFACE WATERS IN THE AREA

INSTRUCTIONS:

1. List all surface water bodies that could potentially be contaminated by a release.
2. Provide a brief description of the water body (e.g., lake, pond, reservoir).
3. For each water body, list the distance from the release source.
4. For each water body listed, identify current and future uses (e.g., agricultural, recreational, municipal, industrial).
5. Provide any additional useful information under comments.

Facility ID: __________

Date: __________

Analyst: __________

Quality Control: __________

Surface Water Body	Description	Distance from Release Source	Current Uses	Future Uses	Comments

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WORKSHEET 5-1

POTENTIAL HUMAN EXPOSURE PATHWAYS

INSTRUCTIONS:

1. List all release sources, transport mechanisms, and transport media (use additional worksheets if necessary).
2. Describe the nature of the exposure point and its location with respect to release source (e.g., nearest residence to volatilization release site, 300 feet NW). Attach a map indicating location of system and exposure points.
3. List exposure route (e.g., inhalation, ingestion).
4. Report the number of people potentially exposed at the exposure point.
5. Indicate if exposure pathways are complete (i.e., where release source, transport mechanism, transport medium, exposure point, and exposure route all exist).

Facility ID: __________

Cluster/Tank System: __________

Date: __________

Analyst: __________

Quality Control: __________

Release Source	Transport Mechanism	Transport Medium	Exposure Point	Exposure Route	Size of Population	Pathway Complete?

Page ____ of ____

WORKSHEET 5-2

POTENTIAL ENVIRONMENTAL RECEPTOR EXPOSURE PATHWAYS

INSTRUCTIONS:

1. List all release sources, transport mechanisms, and transport media (use additional worksheets if necessary).
2. Describe the exposure point.
3. List the exposure route (ingestion, respiration).
4. Describe what is affected at the exposure point (e.g., species list or community description).
5. Attach a complete list of species, population levels, value (if applicable) and structures if not identified on worksheet.

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Source	Transport Mechanism	Transport Medium	Exposure Point	Exposure Route	Species/Community/ Structures	Pathway Complete?

Page _____ of _____

WORKSHEET 5-3

CONTAMINANT CONCENTRATIONS AT HUMAN EXPOSURE POINTS

INSTRUCTIONS:

1. List all human indicator chemicals (use additional worksheets if necessary).
2. List all release media for each chemical: ground water, surface water, soil, and air.
3. List all exposure points for each release medium.
4. List projected short-term and long-term concentrations (lower, upper, and representative) for each exposure point. Be sure to include background concentrations from Worksheet 4-2. Note that water concentrations are in mg/l, air concentrations are in mg/m3, and fish concentrations are in mg/kg. Attach to this worksheet all calculations documenting the concentration estimates to this worksheet.

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Chemical	Release Medium	Exposure Point	Concentration Units	Short-Term Concentration			Long-Term Concentration		
				Lower	Upper	Repres.	Lower	Upper	Repres.

Page ____ of ____

WORKSHEET 5-4

CONTAMINANT CONCENTRATIONS AT ENVIRONMENTAL RECEPTOR EXPOSURE POINTS

INSTRUCTIONS:

1. List all environmental indicator chemicals (use additional worksheets if necessary).
2. List all release media for each chemical.
3. List all environmental receptor exposure points for each release medium.
4. List projected short-term and long-term concentrations for each exposure point. Be sure to include background concentrations from Worksheet 4-2. Note that water concentrations are in mg/l and air concentratons are in mg/m3. Attach all calculations documenting the concentration estimates to this worksheet.

Facility ID: ____________
Cluster/Tank System: ____________
Date: ____________
Analyst: ____________
Quality Control: ____________

Chemical	Release Medium	Exposure Point	Concentration Units	Short-Term Concentration	Long-Term Concentration

Page ____ of ____

WORKSHEET 6-1

COMPARISON OF HUMAN EXPOSURE POINT CONCENTRATIONS TO ESTABLISHED STANDARDS

Facility ID: ________

Cluster/Tank System: ________

Date: ________

Analyst: ________

Quality Control: ________

INSTRUCTIONS:

1. Indicate exposure point and list all indicator chemicals (use additional worksheets if necessary).
2. Record each chemical's concentration range and representative value (from Worksheet 5-3).
3. Refer to Exhibits C-8 to C-12 and any existing state water quality standards to obtain the established standards. Record the value of the standard (include the risk, if known, in parentheses), its source (i.e., Maximum Contaminant Level (MCL), Clean Water Act State Standard (CWASS), Other State Standard (OSS), National Ambient Air Quality Standard (NAAQS), MCL Goal (MCLG), Water Quality Criteria (WQC), or Drinking Water Health Advisory (DWHA)), and any other pertinent information (e.g., whether a DWHA value refers to a one-day or ten-day exposure). Indicate the most appropriate standard with an asterisk.
4. Calculate the ratios of concentrations to standards.
5. Sum the ratios within a standard (e.g., add all the MCL ratios), and sum the most appropriate ratios (no more than one for each chemical). Summed ratios greater than one should not be interpreted too strongly unless further analysis has segregated the chemicals and their standards by critical effect.

Exposure Point: ________

Concentration (circle one): Short-term Long-term

	Chemical	Projected Exposure Point Concentration (mg/l)			Established Quality Standards		Ratio of Exposure Point Concentration to Standard		
		Lower	Upper	Repres.	Value (mg/l)	Source	Lower	Upper	Repres.
1.									
2.									
3.									
					Totals:				
					Most appropriate:				

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WORKSHEET 6-2

SUBCHRONIC GROUND-WATER INTAKES

INSTRUCTIONS:

1. Indicate exposure point and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Using Exhibit 6-2 and/or other available information, calculate a human intake factor by dividing ground-water intake per day by body weight (e.g., 2 l/day/70 kg = 0.029 l/kg/day).
3. List all indicator chemicals (use additional worksheets if necessary) and their short-term concentrations in ground water (from Worksheet 5-3).
4. Determine Subchronic Daily Intake (SDI) using the following formula:
   SDI = Human Intake Factor x Short-Term Concentration.

Facility ID: __________

Cluster/Tank System: __________

Date: __________

Analyst: __________

Quality Control: __________

Exposure Point: __________ Population: __________

Duration of Exposure: __________ Human Intake Factor (l/kg/day): __________

	Chemical	Exposure Point Short-Term Concentration (mg/l)			Daily Intake (mg/kg/day)		
		Lower	Upper	Repres.	Lower	Upper	Repres.
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

Page ____ of ____

WORKSHEET 6-3

CHRONIC GROUND-WATER INTAKES

INSTRUCTIONS:

1. Indicate exposure point and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Using Exhibit 6-2 and/or other available information, calculate a human intake factor by dividing ground-water intake per day by body weight (e.g., 2 l/day /70 kg = 0.029 l/kg/day).
3. List all indicator chemicals (use additional worksheets if necessary) and their long-term concentrations in ground water (from Worksheet 5-3).
4. Determine Chronic Daily Intake (CDI) using the following formula:
   CDI = Human Intake Factor × Long-Term Concentration.

Facility ID: ____

Cluster/Tank System: ____

Date: ____

Analyst: ____

Quality Control: ____

Exposure Point: ____

Population: ____

Duration of Exposure: ____

Human Intake Factor (l/kg/day): ____

Chemical	Exposure Point Long-Term Concentration (mg/l)			Daily Intake (mg/kg/day)		
	Lower	Upper	Repres.	Lower	Upper	Repres.
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						

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WORKSHEET 6-4

SUBCHRONIC SURFACE WATER INTAKES

INSTRUCTIONS:

1. Indicate exposure point and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Using Exhibit 6-2 and/or other available information, calculate a human intake factor by dividing surface water intake per day by body weight (e.g., 2 l/day/70 kg = 0.029 l/kg/day).
3. List all indicator chemicals (use additional worksheets if necessary) and their short-term concentrations in surface water (from Worksheet 5-3).
4. Determine Subchronic Daily Intake (SDI) using the following formula: SDI = Human Intake Factor × Short-Term Concentration.

Facility ID: __________

Cluster/Tank System: __________

Date: __________

Analyst: __________

Quality Control: __________

Exposure Point: __________

Population: __________

Duration of Exposure: __________

Human Intake Factor (l/kg/day): __________

Chemical	Exposure Point Long-Term Concentration (mg/l)			Daily Intake (mg/kg/day)		
	Lower	Upper	Repres.	Lower	Upper	Repres.
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						

Page ____ of ____

WORKSHEET 6-5

CHRONIC SURFACE WATER INTAKES

INSTRUCTIONS:

1. Indicate exposure point and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Using Exhibit 6-2 and/or other available information, calculate a human intake factor by dividing surface water intake per day by body weight (e.g., 2 l/day/70 kg = 0.029 l/kg/day).
3. List all indicator chemicals (use additional worksheets if necessary) and their long-term concentrations in surface water (from Worksheet 5-3).
4. Determine Chronic Daily Intake (CDI) using the following formula:
   CDI = Human Intake Factor × Long-Term Concentration.

Facility ID: ____

Cluster/Tank System: ____

Date: ____

Analyst: ____

Quality Control: ____

Exposure Point: ____ Population: ____

Duration of Exposure: ____ Human Intake Factor (l/kg/day): ____

	Chemical	Exposure Point Long-Term Concentration (mg/l)			Daily Intake (mg/kg/day)		
		Lower	Upper	Repres.	Lower	Upper	Repres.
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

WORKSHEET 6-6

SUBCHRONIC FISH INTAKES

INSTRUCTIONS:

1. Indicate exposure point and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Record the bioconcentration factor (BCF) for each chemical (from Appendix C).
3. Using Exhibit 6-2 and/or other available information, calculate a human intake factor by dividing fish intake per day by body weight (e.g., 6.5 gm/day/70 kg × 1E-3 kg/gm = 9.3E-5 kg/kg/day).
4. List all indicator chemicals (use additional worksheets if necessary) and their short-term concentrations in surface water (from Worksheet 5-3).
5. Determine Subchronic Daily Intake (SDI) using the following formula: SDI = Human Intake Factor × BCF × Short-Term Concentration.

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Exposure Point: ____________

Population: ____________

Duration of Exposure: ____________

Human Intake Factor (kg/kg/day): ____________

	Chemical	BCF (l/kg)	Exposure Point Long-Term Concentration (mg/l)			Daily Intake (mg/kg/day)		
			Lower	Upper	Repres.	Lower	Upper	Repres.
1.								
2.								
3								
4.								
5.								
6.								
7.								
8.								
9.								
10.								

WORKSHEET 6-7

CHRONIC FISH INTAKES

INSTRUCTIONS:

1. Indicate exposure point and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Record the bioconcentration factor (BCF) for each chemical (from Appendix C).
3. Using Exhibit 6-2 and/or other available information, calculate a human intake factor by dividing fish intake per day by body weight (e.g., 6.5 gm/day /70 kg x 1E-3 kg/gm = 9.E-5 kg/kg/day).
4. List all indicator chemicals (use additional worksheets if necessary) and their long-term concentrations in surface water (from Worksheet 5-3).
5. Determine Subchronic Daily Intake (SDI) using the following formula:
SDI = Human Intake Factor x BCF x Long-Term Concentration.

Facility ID: ____

Cluster/Tank System: ____

Date: ____

Analyst: ____

Quality Control: ____

Exposure Point: ____

Population: ____

Duration of Exposure: ____

Human Intake Factor (kg/kg/day): ____

	Chemical	BCF (l/kg)	Exposure Point Long-Term Concentration (mg/l)			Daily Intake (mg/kg/day)		
			Lower	Upper	Repres.	Lower	Upper	Repres.
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								

Page _____ of _____

WORKSHEET 6-8

SUBCHRONIC AIR INTAKES

INSTRUCTIONS:

1. Indicate exposure point and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Using Exhibit 6-2 and/or other available information, calculate a human intake factor by dividing air intake per day by body weight (e.g., 20 m3/day /70 kg = 0.29 m3/kg/day).
3. List all indicator chemicals (use additional worksheets if necessary) and their short-term concentrations in air (from Worksheet 5-3).
4. Determine Subchronic Daily Intake (SDI) using the following formula: SDI = Human Intake Factor x Short-Term Concentration.

Facility ID: __________

Cluster/Tank System: __________

Date: __________

Analyst: __________

Quality Control: __________

Exposure Point: __________

[illegible]opulation: __________

Duration of Exposure: __________

Human Intake Fac[illegible]m3/kg/day): __________

	Chemical	Exposure Point Long-Term Concentration (mg/l)			Daily Intake (mg/kg/day)		
		Lower	Upper	Repres.	Lower	Upper	Repres.
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

Page ____ of ____

WORKSHEET 6-9

CHRONIC AIR INTAKES

INSTRUCTIONS:

1. Indicate exposure point and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Using Exhibit 6-2 and/or other available information, calculate a human intake factor by dividing air intake per day by body weight (e.g., 20 m3/day /70 kg = 0.29 m3/kg/day).
3. List all indicator chemicals (use additional worksheets if necessary) and their long-term concentrations in air (from Worksheet 5-3).
4. Determine Chronic Daily Intake (CDI) using the following formula: CDI = Human Intake Factor x Long-Term Concentration.

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Exposure Point: ________________________________

Population: ____________________

Duration of Exposure: ____________________

Human Intake Factor (m3/kg/day): ____________________

Chemical	Exposure Point Long-Term Concentration (mg/l)			Daily Intake (mg/kg/day)		
	Lower	Upper	Repres.	Lower	Upper	Repres.
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						

Page ____ of ____

WORKSHEET 6-10

OTHER SUBCHRONIC INTAKES

INSTRUCTIONS:

1. Indicate exposure point, type of intake, and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Using Exhibit 6-2 and/or other available information, calculate a human intake factor.
3. List all indicator chemicals (use additional worksheets if necessary) and their short-term concentrations (from Worksheet 5-3).
4. Determine Subchronic Daily Intake (SDI) using the following formula: SDI = Human Intake Factor x Short-Term Concentration.

Facility ID: ________

Cluster/Tank System: ________

Date: ________

Analyst: ________

Quality Control: ________

Exposure Point: ________ Population: ________ Intake: ________

Duration of Exposure: ________ Human Intake Factor: ________

	Chemical	Exposure Point Short-Term Concentration*			Daily Intake (mg/kg/day)		
		Lower	Upper	Repres.	Lower	Upper	Repres.
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

*Air concentrations, in mg/m3.

Page _____ of _____

WORKSHEET 6-11

OTHER CHRONIC INTAKES

INSTRUCTIONS:

1. Indicate exposure point, type of intake, and estimated duration of exposure. Duration should correspond to whether intake is subchronic or chronic (e.g., 3 months for subchronic and 70 years for chronic).
2. Using Exhibit 6-2 and/or other available information, calculate a human intake factor.
3. List all indicator chemicals (use additional worksheets if necessary) and their long-term concentrations (from Worksheet 5-3).
4. Determine Chronic Daily Intake (CDI) using the following formula: CDI = Human Intake Factor x Long-Term Concentration.

Facility ID: __________

Cluster/Tank System: __________

Date: __________

Analyst: __________

Quality Control: __________

Exposure Point: ______________________ Population: __________ Intake: __________

Duration of Exposure: ______________________ Human Intake Factor: ______________________

Chemical	Exposure Point Short-Term Concentration*			Daily Intake (mg/kg/day)		
	Lower	Upper	Repres.	Lower	Upper	Repres.
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						

*Air concentrations, in mg/m3.

Page ____ of ____

WORKSHEET 6-12

PATHWAYS CONTRIBUTING TO TOTAL EXPOSURE

INSTRUCTIONS:

1. List the exposure points for all exposure pathways being evaluated (from Worksheet 5-1) (use additional worksheets if necessary).
2. Determine the exposure pathways contributing to total exposure for each listed exposure point.
3. Note in the comments column which exposure pathways are only short-term, which are non-quantified, and any other pertinent information.

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Exposure Point	Exposure Pathways Contributing to Total Exposure	Comments
1.		
2.		
3.		
4.		
5.		

Page ____ of ____

WORKSHEET 6-13

TOTAL SUBCHRONIC DAILY INTAKE (SDI)

INSTRUCTIONS:

1. Indicate exposure point, number of people, and whether intake estimates are lower, representative, or upper values (complete a separate worksheet for each type of estimate).
2. List all indicator chemicals (use additional worksheets if necessary).
3. Refer to Worksheet 6-12 and determine which exposure pathways are relevant for the exposure point.
4. Record SDIs (in mg/kg/day) for the exposure point from Worksheets 6-2, 6-4, 6-6, 6-8, and 6-10 in the appropriate columns.
5. Determine total SDI by adding the component SDIs for each chemical. For example, ground-water, surface water, and fish intakes would sum together for total oral SDI.

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Exposure Point: ____________

Intake Estimates (circle one): Lower Upper Representative

Population: ____________

	Chemical	Ground Water SDI	Surface Water SDI	Fish Ingestion SDI	Other Oral SDI	Total Oral SDI	Air SDI	Other Inhalation SDI	Total Inhalation SDI
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									

Page ____ of ____

WORKSHEET 6-14

TOTAL CHRONIC DAILY INTAKE (CDI)

INSTRUCTIONS:

1. Indicate exposure point, number of people, and whether intake estimates are lower, representative, or upper values (complete a separate worksheet for each type of estimate).
2. List all indicator chemicals (use additional worksheets if necessary).
3. Refer to Worksheet 6-12 and determine which exposure pathways are relevant for the exposure point.
4. Record CDIs (in mg/kg/day) for the exposure point from Worksheets 6-3, 6-5, 6-7, 6-9, and 6-11 in the appropriate columns.
5. Determine total CDI by adding the component CDIs for each chemical. For example, ground-water, surface water, and fish intakes would sum together for total oral CDI.

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Exposure Point: ______________________ Population: ____________

Intake Estimates (circle one): Lower Upper Representative

Chemical	Ground Water CDI	Surface Water CDI	Fish Ingestion CDI	Other Oral CDI	Total Oral CDI	Air CDI	Other Inhalation CDI	Total Inhalation CDI
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								

WORKSHEET 6-15

CRITICAL TOXICITY VALUES

Page ____ of ____

INSTRUCTIONS:

1. List all components of the waste or indicator chemicals (use additional worksheets if necessary).
2. List subchronic acceptable intake (AIS), chronic acceptable intake (AIC), and carcinogenic potency factor values (including carcinogenicity weight-of-evidence ratings marked in parentheses).
3. For teratogenic chemicals (indicated in Appendix C), list a separate AIS for that effect only.

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Chemical	AIS (mg/kg/day)	AIC (mg/kg/day)	Carcinogenic Potency Factor (kg-day/mg) a/
Inhalation Route:			
1.			
2.			
3.			
4.			
5.			
Ingestion Route:			
1.			
2.			
3.			
4.			
5.			

---

a/ EPA weight-of-evidence rating in parentheses for potential carcinogens (provided in Appendix C).

Page ____ of ____

WORKSHEET 6-16

CALCULATION OF SUBCHRONIC HAZARD INDEX FOR EACH EXPOSURE POINT

INSTRUCTIONS:

1. Identify exposure point and subchronic constituents of concern (use additional worksheets if necessary).
2. List the total oral subchronic daily intake (SDI) and total inhalation SDI in the appropriate columns for each chemical (in mg/kg/day).
3. List route-specific subchronic acceptable intake (AIS) values and calculate route-specific SDI:AIS ratios for each chemical.
4. Sum and record route-specific SDI:AIS ratios.
5. Sum and record total (oral plus inhalation) SDI:AIS ratios only if the SDIs for the two routes refer to the same time period. If the sum is greater than 1, it may be possible to separate the ratios according to health endpoint and complete a separate worksheet for each endpoint.

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Exposure Point: ____________

Intake Estimates (circle one): Lower Upper Representative

Population: ____________

Chemical	Oral (mg/kg/day) SDI	Oral (mg/kg/day) AIS	Oral (mg/kg/day) SDI:AIS	Inhalation (mg/kg/day) SDI	Inhalation (mg/kg/day) AIS	Inhalation (mg/kg/day) SDI:AIS
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						

Sum of Oral SDI:AIS Ratios = ____

Sum of Inhalation SDI:AIS Ratios = ____

Sum Total of All Ratios = ____

Page ____ of ____

WORKSHEET 6-17

CALCULATION OF CHRONIC HAZARD INDEX FOR EACH EXPOSURE POINT

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Quality Control: ____________

Analyst: ____________

INSTRUCTIONS:

1. Identify exposure point and chronic, non-carcinogenic constituents of concern (use additional worksheets if necessary).
2. List the total inhalation chronic daily intake (CDI) and total oral CDI in the appropriate columns for each for each chemical (in mg/kg/day).
3. List route-specific chronic acceptable intake (AIC) values and calculate route-specific CDI:AIC ratios for each chemical.
4. Sum and record route-specific CDI:AIC ratios.
5. Sum and record total (oral plus inhalation) CDI:AIC ratios. If the sum is greater than 1, it may be possible to separate the ratios according to health endpoint and complete a separate worksheet for each endpoint.

Exposure Point: ____________ Population: ____________

Intake Estimates (circle one): Lower Upper Representative

	Chemical	Oral (mg/kg/day)			Inhalation (mg/kg/day)		
		SDI	AIS	SDI:AIS	SDI	AIS	SDI:AIS
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							

Sum of Oral SDI:AIS Ratios = ________

Sum of Inhalation SDI:AIS Ratios = ________

Sum Total of All Ratios = ________

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WORKSHEET 6-18

CALCULATION OF POTENTIAL CARCINOGENIC RISKS FOR EACH EXPOSURE POINT

Facility ID: ____________
Cluster/Tank System: ____________
Date: ____________
Analyst: ____________
Quality Control: ____________

INSTRUCTIONS:

1. Identify exposure point and potentially carcinogenic constituents of concern (use additional worksheets if necessary).
2. List all exposure routes for each chemical.
3. Record chronic daily intake (CDIs) and carcinogenic potency factors (including carcinogenicity weight-of-evidence, e.g., A, B1, B2, etc.) for each chemical and each exposure route.
4. Multiply the potency factor by the CDI to get the route-specific risk; then sum the route-specific risks for each chemical.
5. Sum all of the chemical-specific risks to give an estimate of total incremental risk due to potential carcinogens.

Exposure Point: ____________ Population: ____________

Intake Estimates (circle one): Lower Upper Representative

Chemical	Exposure Route	CDI (mg/kg/day)	Carcinogenic Potency Factor (kg/day mg)	Route-specific Risk	Total Chemical-specific Risk

Total Upper Bound Risk = ____________

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WORKSHEET 7-1

COMPARISON OF ENVIRONMENTAL RECEPTOR EXPOSURE POINT CONCENTRATION WITH WATER QUALITY CRITERIA

INSTRUCTIONS:

1. List all chemicals for the exposure point.
2. List projected total exposure point concentration from Worksheet 5-4. Indicate whether short-term or long-term concentration.
3. List type (e.g., criteria, LOEL) and value of relevant water quality criteria for each chemical.
4. Divide projected exposure concentration by criteria concentration.
5. Sum the ratios for all chemicals at the exposure point.

Facility ID: ____________

Cluster/Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

Exposure Point: ____________

Concentration (circle one): Short-term Long term

	Chemical	Exposure Point Concentration (mg/l)	Type of Criteria	Quality Criteria Value (mg/l)	Ratio
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
				Total:	

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Page ____ of ____

WORKSHEET A-1

TEST FOR APPLICABILITY OF THE SECONDARY CONTAINMENT REQUIREMENT TO THE FACILITY

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

INSTRUCTIONS:

1. Starting with the left-most column, determine which generator class the facility is in.
2. Determine which combination of accumulation time and amount stored on site at one time matches the facility conditions.
3. Place a check in the right-hand column of the row that matches the facility conditions. The column second from the right states whether the facility is exempt from the secondary containment requirement.

NEXT STEPS:

If the facility is not exempt, continue with the screening process (Worksheet A-2).

Quantity of Hazardous Waste Generated in a Calendar Month	Accumulation Time	Amount Stored On Site At Any One Time	Exempt/Not Exempt	Check Applicable Category
< 100 kg	n.a.	< 1000 kg	exempt	____
	< 180 days	1000-6000 kg	exempt	____
	> 180 days	> 1000 kg	not exempt	____
	n.a.	> 6000 kg	not exempt	____
100-1000 kg	< 180 days	< 6000 kg	exempt	____
	> 180 days	n.a.	not exempt	____
	n.a.	> 6000 kg	not exempt	____
> 1000 kg	n.a.	n.a.	not exempt	____

Note: If the facility is found to be exempt from the secondary containment requirement according to the table above, but generates acute hazardous waste (as defined in 40 CFR 261.31, 261.32, and 261.33(e)) in excess of 1 kg in a calendar month, or generates less than 1 kg of acute hazardous waste in a calendar month and more than 1 kg is stored on site at one time for more than 180 days, the tanks storing acute hazardous waste are not exempt from the secondary containment requirement. Generators who have questions as to the applicability of the secondary containment requirement to their tank systems should call the EPA RCRA/CERCLA Hotline at (800) 434-9246, or, in Washington, D.C., at (202) 382-3000.

Page ____ of ____

WORKSHEET A-2

TEST FOR APPLICABILITY OF THE SECONDARY CONTAINMENT REQUIREMENT AND ELIGIBILITY FOR A VARIANCE FOR INDIVIDUAL TANKS

Facility ID: ____________

Tank System: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

INSTRUCTIONS:

1. For each hazardous waste tank system or component for which a variance is being sought, respond yes or no to the questions below.

2. Begin with question 1 and continue to the next recommended question.

NEXT STEPS:

1. If the tank system or component is determined to be eligible to apply for a variance (i.e., a variance is not forbidden and the tank system or component is not exempt from secondary containment), continue to Worksheet A-3 to determine the date by which a notice of application for a variance must be submitted for the tank system or component.

Question	Response (yes/no)	Next Step If Response Yes	Next Step If Response No
1. Does the tank system serve only as part of a secondary containment system used to collect or contain releases of hazardous waste?	____	Exempt.	Continue to next question.
2. Is the hazardous waste stored in the tank absent of free liquids, as demonstrated by EPA Method 9095?	____	Continue to next question.	Go to question 4.
3. Is the tank system located inside a building with an impermeable floor?	____	Exempt.	Continue to next question.
4. Does tank system ancillary equipment include aboveground piping (exclusive of flanges, joints, valves, and other connections), welded flanges, welded joints and welded connections that are visually inspected daily, sealless or magnetic coupling pumps that are visually inspected daily, or pressurized aboveground piping systems with automatic shut-off devices that are visually inspected daily?	____	Ancillary equipment components identified are exempt from secondary containment. Continue to next question.	Continue to next question.

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WORKSHEET A-2 (Continued)

TEST FOR APPLICABILITY OF THE SECONDARY CONTAINMENT REQUIREMENT AND ELIGIBILITY FOR A VARIANCE FOR INDIVIDUAL TANKS

	Question	Response (yes/no)	Next Step If Response Yes	Next Step If Response No
5.	Is the tank system or component new (i.e., did construction begin after July 14, 1986) or has the tank system been repaired after July 14, 1986 after having leaked or been determined to be unfit for use?	____	Continue to next question.	Tank system or component is eligible for a variance.
6.	Is the tank system or component underground?	____	Variance not allowed.	Tank system or component is eligible for a variance.

Page _____ of _____

WORKSHEET A-3

DEADLINES FOR PROVIDING NOTICE OF INTENT TO APPLY FOR A VARIANCE

Facility ID: __________
Tank System: __________
Date: __________
Analyst: __________
Quality Control: __________

INSTRUCTIONS:

1. The following deadlines have been set for tank owners to provide to the Regional Administrator written notice of intent to apply for a variance. If these deadlines cannot be met, the variance application will be denied.
2. Check only one category that describes the hazardous waste tank in question. Some categories may also require a date to be written in that is determined by the tank age.

NEXT STEPS:

1. If the deadline can be met for providing notice of intent to apply for a variance, continue with the screening tool.

Check Applicable Category	Tank Description	Deadline
______	Tank used to store or treat a waste that became hazardous after January 12, 1987.	Replace January 12, 1987 in the below cutoff dates and age categories with the date the waste was made hazardous, then determine which category the tank falls under and write the deadline date below. Date: ______
______	New tank (construction began after July 14, 1986)	30 days prior to entering a contract for for installation.
______	Existing tank (regardless of whether the age of the tank system is known) used to store or treat hazardous waste identified by the following EPA hazardous waste numbers: F020, F021, F022, F026, or F027.	January 12, 1987
For an existing tank system of known and documented age:		
______	Tank system 13 or more years old as of January 12, 1987.	January 12, 1987
______	Tank system less than 13 years old as of January 12, 1987.	Before the tank reaches 13 years in age. Date: ______
For an existing tank system for which the age cannot be documented:		
______	Facility less than 7 years old as of January 12, 1987.	January 12, 1993 (6 years after January 12, 1987)
______	Facility between 7 and 13 years old as of January 12, 1987.	Before the facility reaches 13 years in age. Date: ______
______	Facility greater than 13 years old as of January 12, 1987.	January 12, 1987

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WORKSHEET A-4

WASTE CONSTITUENT CONCENTRATIONS AND COMPARISON TO STANDARDS

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

INSTRUCTIONS:

1. List all waste constituents (use additional worksheets if necessary).
2. Record each chemical concentration range and representative value.
3. Refer to Exhibits C-8 through C-12, and/or, for federally-approved state water quality standards, the appropriate state agency, to obtain established water standards. Record the value of the standard, its source (i.e., Maximum Contaminant Level (MCL), MCL Goal (MCLG), federally-approved state standard (FASS), Water Quality Criteria (WQC), or Drinking Water Health Advisories (DWHA)), and any other pertinent information (e.g., whether WQC value refers to a one-day or ten-day exposure). Indicate the most appropriate standard for each chemical with an asterisk.
4. Calculate the ratios of concentrations to standards.
5. Sum the ratios within a standard (e.g., add all MCL ratios) and sum the ratios of the most appropriate standards (no more than one for each chemical).

NEXT STEPS:

1. If several representative concentrations exceed standards by several orders of magnitude, then user may want to reconsider applying for a variance.

Chemical	Chemical Concentration (mg/l)			Established Water Quality Standards		Ratio of Chemical Concentration to Standard		
	Lower	Upper	Repres.	Value (mg/l)	Source	Lower	Upper	Repres.
1. ________	____	____	____	________	________	____	____	____
				________	________	____	____	____
2. ________	____	____	____	________	________	____	____	____
				________	________	____	____	____
				________	________	____	____	____
3. ________	____	____	____	________	________	____	____	____
				________	________	____	____	____
				________	________	____	____	____
				________	________	____	____	____
				Total:	________	____	____	____
					________	____	____	____
					________	____	____	____
					Most apprpriate:	____	____	____

WORKSHEET A-5

HYDROGEOLOGIC CONSIDERATIONS

Page ____ of ____

INSTRUCTIONS:

1. Provide a response to each question.
2. If the applicant wants to provide more accurate responses to the questions, the applicant may investigate the listed data sources.

NEXT STEPS:

1. If the applicant has no knowledge or information relating to the presented questions, or most responses indicate a high risk situation, applicant may want to reconsider applying for a variance.

Facility ID: ____

Date: ____

Analyst: ____

Quality Control: ____

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Question	Response (yes/no)	Data Source	Potential Risk Lower	Potential Risk Higher	Comments
Is the hazardous waste tank located below the water table level?	____	Site Operational Records U.S.G.S. U.S.D.A. (Soil Conservation Service) Local Water Supply Agencies and Companies	--	Yes	Any leakage results in immediate contamination of ground water. Risk associated with a "No" answer is dependent on many other factors.
What is the depth to water at the hazardous waste tank site? a/	____	U.S.G.S. U.S.D.A. (Soil Conservation Service) Local Water Supply Agencies and Companies Well logs or hydrogeological reports.	>50 ft.	<50 ft. g/	Determines the depth of material through which a contaminant must travel to reach an aquifer. The extent of attenuation or removal of contaminant generally increases with increasing depth.
What is the unsaturated zone at a hazardous waste tank site composed of? b/	____	U.S.D.A. (Soil Conservation Service): Soil Maps Soil Survey Reports	Shale Silt/Clay Glacial Till Karst Limestone c/	Thin or Absent Sand or Gravel	More porous materials such as sand or gravel or the absence of an unsaturated zone between the tank and the ground water indicates faster transport of potential contaminants to ground water.

WORKSHEET A-5 (continued) Page ____ of ____

HYDROGEOLOGIC CONSIDERATIONS

Question	Response (yes/no)	Data Source	Potential Risk		Comments
			Lower	Higher	
Is the net recharge rate high or low (0-2"/yr) at the site? d/	____	U.S.G.S. State Department of Water Resources Local Water Supply Agencies or Companies U.S.D.A. (Soil Conservation Service) NOAA (National Weather Service)	Low	High	Generally, the greater the recharge, the greater the potential for ground-water contamination due to greater transport to water table. Generally, areas with unconfined aquifers and high recharge are at greater risk than areas with confined aquifers.
Is the aquifer under a hazardous waste tank site confined or unconfined? e/	____	U.S.G.S: Water Resources Division State Department of Water Resources Local Water Supply Agencies or Companies	Confined	Unconfined	Generally, unconfined aquifers are considered to be at higher risk than confined aquifers due to the ease of contaminant movement into them.
What is the composition of aquifer media at hazardous waste tank site? f/	____	U.S.G.S. State Department of Water Resources Local Water Supply Agencies or Companies	Massive Shale Fractured Bedrock	Karst Limestone Sand and Gravel	Aquifer media exerts the major control over the route and path a contaminant must follow. If aquifer is very deep, this consideration is much less important.
Is the hazardous waste tank located on or near to a fault(s) or fault zone?	____	U.S.G.S. Geological Maps, Bulletins, or Reports	No	Yes	These features can provide major pathways of migration for contaminant transport to ground water.

Page ____ of ____

WORKSHEET A-5 (continued)

HYDROGEOLOGIC CONSIDERATIONS

Question	Response (yes/no)	Data Source	Potential Risk		Comments
			Lower	Higher	
Is the hazardous waste tank located in a flood-prone area?	______	NOAA (National Weather Service): Flooding levels (elevations U.S.G.S: Topographic maps (site elevations) Federal Insurance Administration: Flood insurance rate map Flood hazard boundary map	No	Yes	Flod-prone areas include: Coastal areas: (coastal barrier islands, eroding shorelines) Channel encroachment areas Wetlands (frequently flooded) 100-year floodplain. In the event of a release, flooding will affect the fate and transport of waste constituents.

a/ Depth to water being the depth to the water surface or water table (i.e., pore spaces filled with water) in an unconfined aquifer, or to top of aquifer if confined.

b/ Unsaturated zone includes soil and rock material down to the water table or aquifer.

c/ Karst topography is characterized by closed depressions or sinkholes, caves, and underground drainage.

d/ Recharge being the amount of water that penetrates the ground surface and reaches the water table. Depends on precipitation, evaporation (evapotranspiration), and unsaturated zone media.

e/ A confined aquifer being one separated from upper materials by a layer of impermeable or low permeability material.

f/ Refers to the consolidated or unconsolidated medium which serves as the aquifer (an aquifer defined as being a medium which will yield sufficient quantities of water for use).

g/ A majority of beneficial use ground water in the U.S. being found at less than 50 feet.

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WORKSHEET A-6

SURROUNDING WATER USE, WATER QUALITY, AND LAND USE CONSIDERATIONS

INSTRUCTIONS:

1. Provide a response to each question.
2. If the applicant wants to provide more accurate responses to the questions, the applicant may investigate the listed data sources.

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

NEXT STEPS:

1. If the applicant has no knowledge or information relating to the presented questions, or most responses indicate a high risk situation then the applicant may want to reconsider applying for a variance.

Question	Response (yes/no)	Data Source	Potential Risk Lower	Potential Risk Higher	Comments
Is the ground water at or near the hazardous waste tank site saline (or have a total dissolved solids (TDS) concentration over 10,000 mg/l) to an extent which would not allow drinking or other beneficial uses?	______	Nation Water Well Association Library (Ohio) U.S.G.S.: Basin Investigations NAWDEX a/ Army Corps of Engineers Local sources: Planning Boards Government Councils State Environmental Protection Offices State Universities	Yes	No	If yes, and is hydrogeologically isolated and is of limited beneficial use, may be appropriate to continue screening and variance process.
Is ground water at a site considered to be ecologically vital (i.e., does ground water supply a unique terrestrial or aquatic habitat associated with surface water bodies that if polluted would destroy a unique habitat)?	______	U.S. Fish and Wildlife Service State Endangered Species Coordinator National Park Service U.S. Forest Service U.S. Bureau of Land Management Army Corps of Engineers	No	Yes	If ground water is ecologically vital a successful variance demonstration is unlikely.
Sensitive ecological systems include:					
a) Does ground water at a site supply a habitat for an endangered or threatened species of animals and/or plants?	______		No	Yes	Pursuant to the Endangered Species Act of 1973.

WORKSHEET A-6 (continued)

SURROUNDING WATER USE, WATER QUALITY, AND LAND USE CONSIDERATIONS

Question	Response (yes/no)	Data Source	Potential Risk Lower	Potential Risk Higher	Comments
b) Is hazardous waste tank located in wetlands?	_______		No	Yes	Wetlands are ecologically sensitive as they support vegetation adapted for life in saturated soil conditions. May be protected under state statutes, the Clean Water Act, or Executive Order 11990.
c) Is hazardous waste tank located in a coastal area?	_______		No	Yes	May be regulated under the Coastal Zone Management Act, or State Coastal Zone Management Programs.
d) Is hazardous waste tank located in any other sensitive environmental area -- such as watersheds selected by state and local governments for protection?	_______		No	Yes	
Is ground water at or near a hazardous waste tank site "irreplaceable"?	_______	Local Water Supply Agencies and Companies	No	Yes	If ground water is irreplaceable and highly vulnerable to contamination, a successful variance demonstration is unlikely.
This can be assessed by the following questons:					
a) Does ground water serve a substantial population?	_______		No	Yes	A substantial population being approximately 2500 people within or near the 2-mile review radius. b/
b) Is ground water of surrounding hazardous waste tank site located in areas where there is no alternative source of drinking water or an insufficient alternative source for a substantial population?	_______		No	Yes	Includes islands, peninsulas, and isolated ground water over bedrock.

Page ____ of ____

WORKSHEET A-6 (continued)

SURROUNDING WATER USE, WATER QUALITY, AND LAND USE CONSIDERATIONS

Question	Response (yes/no)	Data Source	Potential Risk		Comments
			Lower	Higher	
Is ground water at or near hazardous waste tank site located in an aquifer designated as a Sole Source Aquifer under the Safe Drinking Water Act?	______	Local Water Supply Agencies and Companies	No	Yes	If yes, potential risk is greater.
Is ground water at or near the site a current or potential source of drinking water?	______	Local Water Supply Agencies and Companies	No	Yes	If yes, potential risk is greater.
Can be assessed by: a) Are there operating drinking water wells (or springs) in the area (within the 2-mile review radius)? b) Would a well or spring in the area be capable of yielding a quantity of drinking water sufficient for the needs of an average family (150 gal/day)?					
Is the hazardous waste tank located near a scenic river or recreational area such that leakage of hazardous waste would adversely affect the area?	______	National Park Service County Recreation Department	No	Yes	Such areas may be protected under State statutory and/or regulatory authority.
Are there agricultural lands located in the area of the hazardous waste tank?	______	U.S. Department of Agriculture (Soil Conservation Service)			
If so, can potentially adverse effects be identified if leakage occurs from a hazardous waste tank?	______		No	Yes	Protection policies are identified in the USDA Farmland Protection Policy and the EPA's "Policy to Protect Environmentally Significant Agricultural Lands."

WORKSHEET A-6 (continued)

SURROUNDING WATER USE, WATER QUALITY, AND LAND USE CONSIDERATIONS

Question	Response (yes/no)	Date Source	Potential Risk		Comments
			Lower	Higher	
Is hazardous waste tank located such that releases could migrate directly to drinking water or a drinking water supply?	______	Local Water Supply Agencies and Companies	No	Yes	If yes, can pose a threat to human health.
Does ground water at or near a hazardous waste site discharge to surface water bodies that serve as a drinking water supply	______	U.S.G.S. Basin Investigations NAWDEX a/ Local Water Supply Agencies and Companies	No	Yes	If yes, surface-water quality may be degraded.

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a/ National Water Data Exchange

b/ Source: EPA, *Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy*, Office of Ground-Water Protection, December 1986.

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WORKSHEET A-7

SCREENING OF POTENTIAL EXPOSURE PATHWAYS

Facility ID: ____________

Date: ____________

Analyst: ____________

Quality Control: ____________

INSTRUCTIONS:

1. List all release sources and mechanisms by release medium.
2. Describe the nature of the exposure point and its location with respect to release source (e.g., nearest potable well to release site, 300 feet NW). Denote significant exposure points with an asterisk.
3. List exposure route (e.g., ingestion).
4. Report the number of people potentially exposed at the exposure point.
5. Determine number, location, and nature of sensitive population.
6. Mark where exposure pathways are complete (i.e., where release source, transport medium, exposure point, and exposure route all exist).

Release/ Transport Medium a/	Release Source/ Mechanism	Exposure Point	Exposure Route	Number of People	Sensitive Population	Pathway Complete
Ground water						
Surface water						

a/ Direct air exposure need not be considered because secondary containment generally would not significantly reduce risk due to direct air exposure. For aboveground tank systems containing highly volatile constituents, however, secondary containment, by restricting the surface area over which a release could spread, would reduce the volatilization rate of the constituent and, hence, the risk from direct air exposure.